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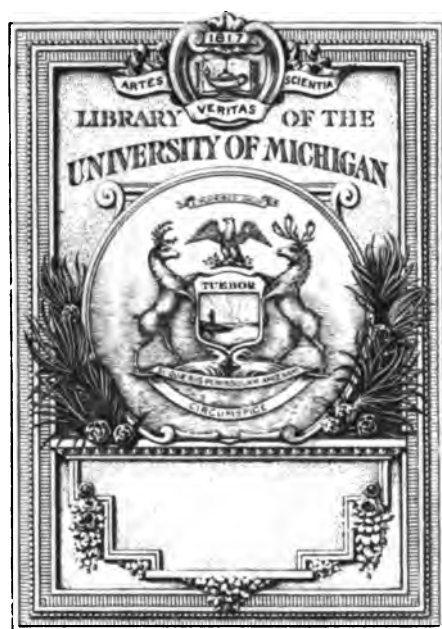
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NORTH DAKOTA AGRICULTURAL COLLEGE

North Dakota
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EXPERIMENT STATION

FOR

NORTH DAKOTA

Bulletin No. 107

Wheat:

Soil Troubles and Seed Deterioration.

Causes of Soil Sickness in Wheat Lands.

Possible Methods of Control.

Cropping Methods with Wheat.

By H. L. Bolley.

Any farmer, teacher, or student in the State may have this Bulletin
mailed to his address, free of charge upon application

FARGO, NORTH DAKOTA, U. S. A.

DECEMBER, 1913

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General

INTRODUCTION

AND

ACKNOWLEDGEMENTS

This bulletin is intended as an outline statement of the conditions found in many wheat growing regions in which a rather constant or one-crop system of farming prevails. It is written in its present form with the purpose of giving a general view regarding the relations of root and soil diseases to wheat cropping. In its general aspects, it affords a somewhat novel explanation of the effects of constant cropping to one kind of a crop.

Some of the diseases to which we refer in this bulletin have been studied by others. The conclusion to which we have come, that improper handling of seed and of soil associated with constant cropping brings about soil-sickness for wheat through the introduction of wheat diseases into the soil and seed and accounts for the deteriorated condition of the wheat, is essentially new.

At first thought, some of the conclusions drawn would seem to be in strong contrast if not in opposition to what are commonly known as best methods of agriculture. Many have persistently insisted that the trouble under the one-crop system is due to the fact that fertility is lost and that a crop rotation is primarily a scheme for resting the soil. Our experiments seem to prove conclusively that the explanation for crop rotation can better be placed upon a basis of sanitation than upon a mere plan of saving fertility. The results obtained seem to explain many of the difficulties in cropping such as arise in the assignment of crops in rotation, use of manures, fertilizers, etc., which have heretofore been difficult of explanation.

The problem of wheat deterioration is one of such complex bearing upon all of the methods of farm cropping that it is not possible, in this preliminary bulletin, to give the complete tabulated data of the various lines of investigation upon which the general conclusions are founded. The purpose is to give proper detail to the various phases of the subject in separate bulletins to follow. There are now under construction three bulletins: (1) dealing specifically with the parasites, their classification, and their relations to the tissues of the wheat plant; (2) the relationship of cropping methods, manures and fertilizers to

disease and crop production; (3) wheat breeding, seed selection and seed treatment in relation to disease control.

For a number of years our experiments and investigations have been planned without reference to the work as done by any other investigators, for the specific purpose that our conclusions, when finally drawn, might be the right answer to what is the cause of deterioration in seed grains, under an approximately constant cropping system.

Acknowledgements: The problem has been approached from many angles. The writer has been able to come to the conclusions which are here given in this general publication largely because of the conscientious and consistent help given by many assistants acting thru a number of years of experimental work, both in the field and in the laboratory, and I wish here to give special acknowledgements for that assistance, particularly to Thos. Manns, Fred J. Pritchard and H. F. Bergman, former assistants in this department of the experiment station, and particularly to Messrs. Mercer, Milbrath, Doryland and Stevens, present assistant botanists. Each of these men has, at different times, had assigned to him definite portions of the work, and his care has made it possible for the entire work to be properly summarized. I wish to especially acknowledge the kindly supervision and encouragement of Director J. H. Worst thruout the long period of investigations when, at times, it seemed that there could be little hope that such experiments could lead to any light likely to further agricultural methods.

That the bulletin may be read with a somewhat clearer understanding of its aims, the following short statements are given:

STATEMENTS.

1. Constant or rather constant culture of wheat on the same lands bring about **wheat-sickness**, wheat-sick soil.

2. Wheat does not thrive well in the presence of its own dead bodies, no matter how fertile the soil.

3. Constant wheat cropping does not especially exhaust or use up the fertility, plant foods, more rapidly than crops in series.

4. Best evidence indicates that constant wheat cropping does not introduce into the soil any permanent excrement or poisons detrimental to wheat.

5. Constant wheat cropping tends to introduce with the seed, stubble, roots, etc., a number of wheat disease producing fungi. These fungi destroy, blight and rot off the roots of the wheat plants, and live internally in the straw and the seeds.

6. These fungus parasites of wheat accumulate in fertile soils and bring about a condition of wheat-sickness, "wheat-tired soil," which has led many to assume that such soils are in part or wholly exhausted for wheat.

7. Wheat-sick soil and wheat-sick seed are the chief causes of the trouble which millers complain of as deteriorated grain.

8. The fungi attack the roots of the wheat, the leaves, stems and young developing grains and produce many peculiar evidences of damage to the crop. They are the chief cause of the failure of wheat to properly stool on fertile soils. They make the plants live almost wholly upon the surface of the soil even tho the land is deeply and well worked. They cause the following peculiar features: wilting and blighting of embryos and plantlets in first leaf, "tip burn" and "sun scald" of young plants at stooling time, blighting of side stool at shot-leaf period, black-foot or creosote colored stems below ground line; death of wheat in alkaline areas otherwise not sufficiently alkaline to injure the crop, incomplete filling of upper head parts, shrivelled grains, "black-pointed" grains, purplish or pink grains, white-bellied grains, pie-bald grains, and play a large part in the troubles spoken of as "bleached and blistered" grain.

9. There are a number of these wheat fungi and together or severally they largely account for many anomalies of cropping. For example, some times fresh barnyard manures are particularly injurious to wheat even on rather poor lands. Sometimes the best methods of tillage fail to give plump wheat on good soils and under good weather conditions. Sometimes the most widely approved series of crop rotation fails to produce wheat of proper grade under otherwise high culture and soil quality. Sometimes the most approved use of artificial fertilizers fail to give proper results even when applied to rather poor wheat soils. Finally it is not at all uncommon for the best variety, best selected, best treated seed to fail to properly reproduce itself, even under high class soil, tillage and climatic conditions. These failures of the past may be explained by the fact that the root and seed diseases of wheat were present—introduced some times by the seed, sometimes by the fresh, uncomposted strawy manures, sometimes by wind-blown or water-washed dirt, etc.

10. This disease theory rests on facts of nature. It helps to explain many good results which are sometimes noticed under intensive, proper, careful farming. For example: Proper summer working or soil tillage tends to firm down the soil and these wheat fungi do not develop rapidly or deeply in a firm compact seed bed. Such proper soil tillage keeps the upper

layers of the soil stirred until the sunlight and aeration tends to purify the soil from the germs of the wheat diseases. The purified soil not only becomes more nearly free from weed seeds, but also largely free from the root destroying fungi. The wheat roots can then penetrate more deeply. Properly composted barnyard manures tend to become free from such wheat root diseases. Properly selected, plump, bright colored, heavy weight seed grains contain less parasitic fungi under the bran layers than do the low grade shrivelled or water injured grains. The fanning mill, properly used, tends to discard grains which contain the wheat-sick fungi on the interior. Proper treatment of seed wheat not only kills smut spores, but kills the spores of the wheat root diseases which are commonly abundant on the exterior of even the highest grade wheat. Wheat which has been threshed before it is allowed to get wet makes better seed wheat than that which gets wet in the grain or sheaf because such dry threshed, dry saved seed does not give the wheat-root fungi opportunity to grow under the bran layers of healthy seeds or grains.

11. Wheat deterioration in the fertile wheat growing areas of Northwest America involves soil and seed problems directly analogous to those in the case of the flax crop or potato crop. **It is not primarily a problem of soil fertility lost, but of disease present.**

12. Our "wheat-sick" soils are properly described by the word. They have not particularly lost their capacity to grow normal wheat. They will do it again when most of our farmers understand that proper wheat farming involves a proper sanitary handling of the soil and seed.

13. Fertilizers and crop rotation will give a better account of themselves when the farmers sow purified seed on purified soil.

14. The proper foundations for a crop rotation rests in the use of comparatively non-related crops in series,—those which do not bear each others' diseases.

15. Fresh barnyard manures containing wheat refuse, straw, etc., should not be used for immediate or direct application to the wheat crop. It should either be purified by composting or be applied to some crop not closely related to wheat.

16. Artificial fertilizers, if applied, should be used with the view of giving a proper balanced food relation for the even development of a sturdy resistant leafage and straw.

17. Proper methods of soil tillage and handling of manures and artificial fertilizers are not merely measures for supplying plant food, but also involve vital features of a sanitary nature.

18. In cereal cropping, air, water and soil fertility (plant foods) are primary matters of crop productivity.

19. The problem of grain deterioration, as now observed by farmers, millers, chemists and agriculturists, the writer thinks, involves the question: "What is the matter with the crop and its product?", rather than: "What is the matter with the soil?"

20. Deteriorated wheat, as seen in depressed yields and low quality, as now quite commonly produced in the great natural wheat-producing regions of this country, is not, primarily, a matter of lost fertility, or of modified chemical content of the soil, but is specifically a problem of infectious disease which is superimposed upon the problems of soil and crop management. Crop rotation, for example, is not, primarily, a farm process which is likely to conserve the fertility of the soil, but when properly arranged in a system so that the proper crops follow one another, it is definitely a sanitary measure tending to maximum production.

21. Wheat-root fungi and their spores are drifted from field to field and persist in the soil in exactly the same sense as weed seeds are distributed. This accounts for much new land infection.

22. In so far as other cropping plants and their diseases are mentioned in this bulletin, they are used only for illustration purposes because more commonly understood.

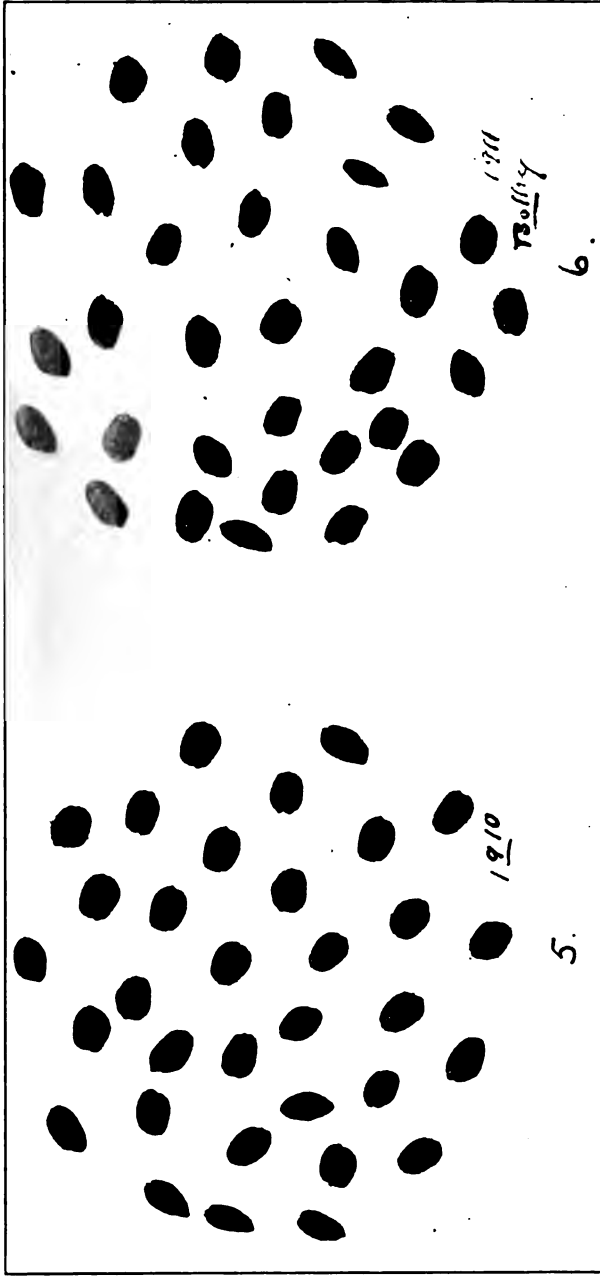


Fig. 1.—Effect of a combination of root diseases and seed blighting diseases upon wheat of high quality when seeded upon soil under constant cropping to wheat. (5) Sample of high grade red fife, grown in Western Canada, Crop 1910. (6) Grains showing the average character of the crop produced in 1911 from the seed as shown at (5) when seeded upon wheat-sick soil. Notice the shrivelled grains, the loss of weight and wrinkled bran. Such seed as shown at (5) can be essentially purified of disease by seed treatment; that shown over (6) cannot. (See Figs. 16, 17 and 18.)

WHEAT

Soil Troubles and Seed Deterioration.

Causes of Soil Sickness in Wheat Lands.

Possible Methods of Control.

Cropping Methods With Wheat.

H. L. Bolley, Botanist.

The Wheat Crop: Wheat is, no doubt, one of the oldest of food producing crops. There are no very definite records with regard to its early existence as a crop, but the types of grain which have been found in old monuments and mentioned in historical writing show that the seed of this crop has been always largely depended upon by inhabitants of the earth for food. It is evident that the plant was essentially perfected in the form that we now know this cereal at a very early time. The crop has been grown chiefly for the seed and used as meal or for flour purposes. Essentially all other portions of the crop of value are represented in by-products from the manufacture of flour. The chief exception being the use of the crop for grazing purposes and the straw in paper making. In regions where the soil and atmosphere are too dry for ordinary growths of hay, the crop has been successfully used for the production of forage cut as hay.

Most American and European farmers have used the thrashed straw as forage and under certain conditions this straw is of fair feed value when fed with more nutritious materials.

No doubt the feeding of this straw and the use of the same for stable bedding has also had a great influence upon wheat cropping due to the influence of the straw upon the manure and the consequent effect due to the general distribution of crop pests in the manures to the lands.

Origin of the Wheat Plant: The wheat plant has probably been developed from some of the wild grasses of the old world, either of North Africa, or Southwest Asia. The forms of the crop now known are to be looked upon as the survival of the most useful food producing types of some native grasses which were early used as grain producing plants under aboriginal cropping efforts. The present wheat plants have probably been modified for grain production thru natural, intermittent and rather unintelligent methods of selection from one or more native wheat-like grasses. The most probable ancestral types now

growing in the old world are *Triticum hermonis*¹ (wild emmer) and *Hordeum Spontaneum*² (wild barley). The nearest related plants in this country are the various species of wheat grasses, as quack-grass, slender wheat grass, western wheat grass, etc.

Of the changes during the long period in which the wheats were under course of development from the wild types to the edible forms which we now know, history is silent. The grain producing capacity and food value of the chief forms now known to us have probably not been greatly improved since written history, but the number of varietal strains which have

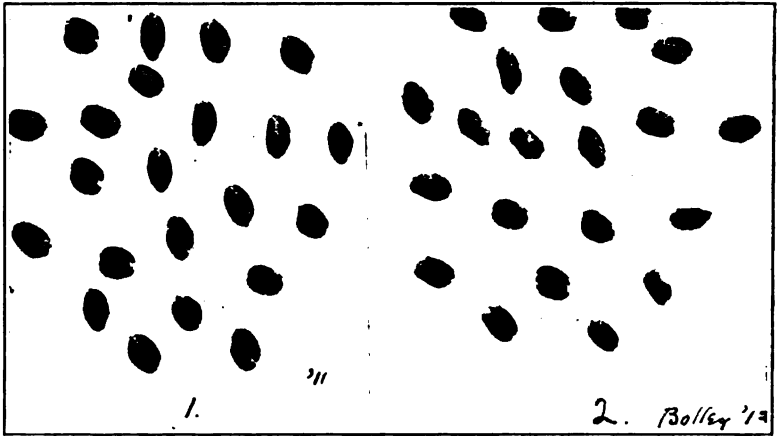


Fig. 2.—High class seed, when placed upon wheat-sick ground tends to produce black points. Seeds of the character shown at (1) coming off from new lands, when seeded upon old wheat stubble (wheat-sick soils) usually produce a high percentage of black-pointed grains as shown at (2). (See fig. 3 also table No. XI.)

been separated out, within comparatively late years, is large, and the improvement in methods of farming and the development in machinery to facilitate proper cropping have made wonderful strides during the last fifty years. Conditions have thus been brought about thru which possibly greater yields have been obtained from the crop than was possible under the old methods of agriculture. It is probable that in late years the increased world output, in bushelage, is due more specifically to increased acreage and to improved methods of tillage than to specific seed improvement. It is, however, a matter of

1. Aaronsohn, Aaron, U. S. Dept. of Agriculture, Bureau of Plant Industry, Bulletin No. 180, Pages 42 to 52 inclusive.

2. Cook, O. F., U. S. Dept. of Agriculture, Bureau of Plant Industry, Bulletin 274, Page 13.

great encouragement to know that the wheat plant is subject to variation as to type and that new varieties can be produced with comparative ease. With the great facilities for such work and for making permanent records of investigation, it ought now to be comparatively easy to develop thru breeding and cultivation methods wheat types of much greater yielding capacity than ever heretofore known. To get and maintain such improved yielding capacity, it will be necessary for all parties interested in the crop, especially the growers of seed, to understand the conditions under which the crop grows and the various conditions which tend to hold it upon a low level of production.

The Influence of Climate and Soil: In late years, there has probably been but slight change in the chief forms of wheat in }

Table No. 1.—Composition of Typical Soils of the Red River Valley in the Constant Wheat Cropping Districts as Compared to the Average of the Most Productive Illinois Soils: (Table compiled from Bulletin 100, N. D. Experiment Station. Original Chemical Data by Prof. E. F. Ladd and the Chemical Department of Illinois University.)

Pounds per acre in two million (top 7 inches).

Locality	Total	Acid Soluble			
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Bathgate	7560	1460	11560	18880	14360
Fargo	7200	2520	13600	19860	6020
Wahpeton	5520	1040	6540	11800	7940
Average of the 3 N. D. Samples	6760	1673	10566	16846	9940
Average of most productive soils of Illinois	8000	1700	7500	.....	.....

The chemical analyses of the soil as given for the Fargo district was made upon a plot of ground which had been in practically constant wheat culture cropping for approximately forty years. It is a plot which under ordinary methods of cropping produces almost regularly year by year a very low grade of deteriorated wheat, shrivelled and diseased. It will be seen, however, that its fertility and total nitrogen approximates the best Illinois soil and in available phosphate and potash excels the Illinois soil. *One can hardly assume that such soils as here analyzed should fail to produce wheat because of lack of fertility. (See Figs. 2, 27 and 28.)*

their ability to produce grain, yet there are many facts recorded which show that the growth characteristics, type or plant form, seed production and food value of the crop are remarkably plastic characters which respond profoundly to the influence of soil, climate and cropping methods. We should, therefore, be able to make selections in such manner as to tend to improve the yielding qualities of the crop and its food value, and it ought to be possible to plan such experiments as shall definitely make clear the conditions of soil and atmosphere and the biological (life) relations which are most essential to develop a particular wheat quality, as milling value, disease resistance, etc. To make such improvements in variety or types lasting, it is essential that in wheat cropping the full life relations should be taken into consideration. The influence of disease

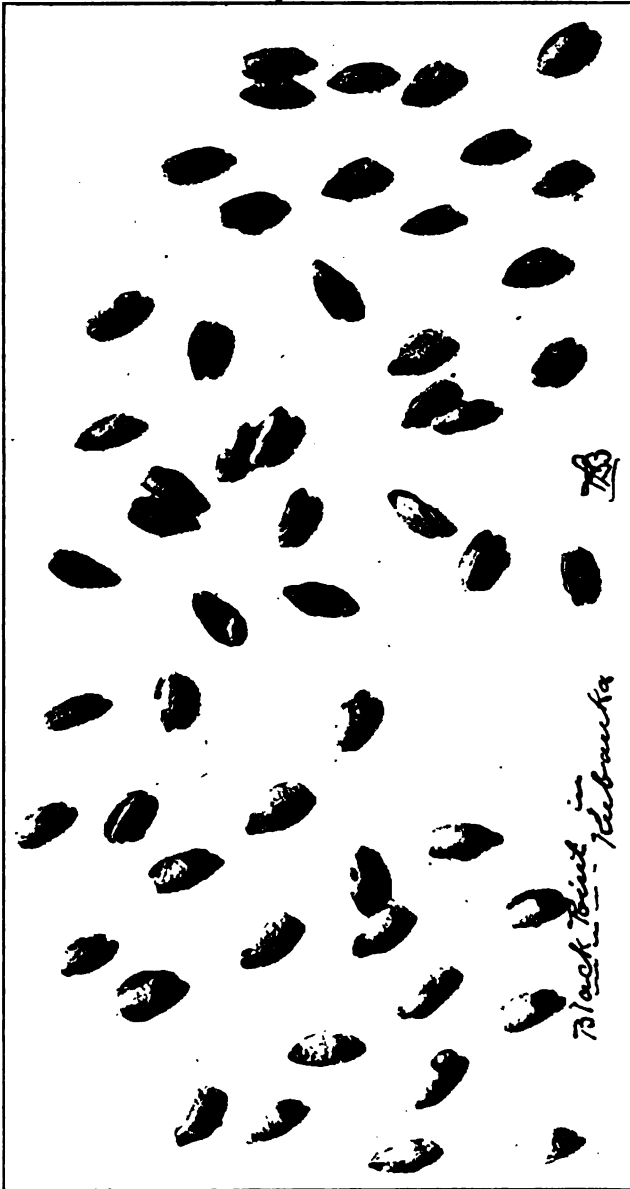


Fig. 3.—Durum wheats are natives of clear, dry, cold atmospheric conditions, and of essentially dry land conditions. They deteriorate very rapidly when brought under culture where there is much soil moisture and high nitrogen fertility. They deteriorate particularly when placed under such conditions upon wheat-sick soil. Seeds of hard, clear, amber color often produce the first year seed of the character shown in this photograph when placed upon wheat-sick stubble lands. Notice the black points and the blistered conditions of the bran. The bran layers are raised or lifted because of the presence of the internal fungi. Germination in such seed is always very low even tho saved without becoming wet at harvest time.

in relation to climatic effects is not at present given proper weight.

Wheat Types: The chief types of wheat are not of late origin, but have been separated by selective methods from a large mixture of types which have come about thru migrations of people from the original wheat producing regions. The most typical forms have, no doubt, been fixed by climatic and soil conditions under primitive methods of agriculture thru a type of natural selection acting over long periods of time in a single locality.

The Nature of the Wheat Plant: The wheat plant is an annual and starts from seed only. As to environment and essential conditions, one readily recognizes two forms: (1) Winter annual (winter wheat). (2) Summer annual (Spring

Table No. II.—Fungus Content of Interior of Wheat Grains: This table shows the results obtained from counting the kinds of fungi developed from the interior of variously "off" colored wheat grains. The methods consisted in the formaldehyde disinfection of the seed and germination on agar. Marquis Wheat, grown on farm of James Austin, Hannaford, N. D., crop 1912. (Cultures by Milbrath.)

The number of grains examined in this particular sample of wheat were 345. The table shows the percentage of cases in which the various fungi developed.

Organisms.	From Black Pointed Grains	From Pink Colored Grains	From Wrinkled Grains	From Bleached Grains	From Rough Grains
<i>Alternaria</i>	80	4	15	16	42
<i>Fusarium</i>	8	73	30	24	12
<i>Helminthosporium</i>	8	0	12	6	7
<i>Colletotrichum</i>	0	0	38	26	5
<i>Bacteria</i>	2	8	1	25	30
Pure	7	15	4	2	4

As in the case of the examination of the interior of the nodes and internodes and stem lesions one grain may often contain two or more of these fungi in association. It is evident, however, that the black pointed grains are most commonly associated with the genus *Alternaria* and the pink grains with *Fusarium* but that practically all of the kinds, particularly *Colletotrichum* and *Helminthosporium*, show capability of invading grains which have been dampened, locating beneath the bran layers.

wheat). The common wheats are readily separated because of the peculiarities of the grain and the flour quality into two types: (1) Hard or Durum varieties, and (2) Soft or bread varieties. Such terms are not particularly distinctive, but rather collective and comparative being based largely upon milling and commercial terminologies. A "hard" variety may be soft and a "soft" variety may be hard in texture, according to climate, soil and culture conditions. Thus some so-called bread wheats, as Scotch Fife, grown under dry atmosphere and soil conditions characteristic of certain regions of the

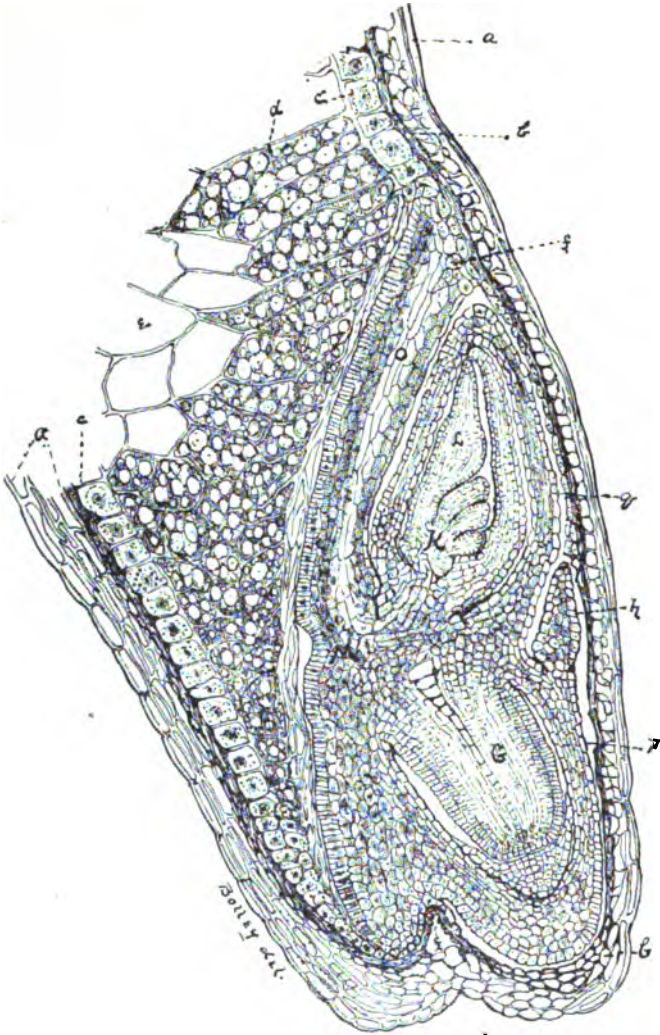


Fig. 4.—Longitudinal section of a Fluke wheat grain cut thru the base of a normal grain so that the section passes thru the middle of the embryo and the deepest portion of the groove of the grain. The section shows the location of the embryo, with reference to the bran layers. Notice at (G) the first root and the open spaces about it and other open spaces elsewhere under the bran or outer skin enclosing the embryo and other parts of the grain. The filaments of the fungi first invade the open spaces then attack the young plant. (a) Outer bran layer; (b) Inner bran layer under which the fungi usually penetrate; (c) Sheath covering the bud end of the embryo (plumule); (L) First leaf; (o) Feeding organ (scutellum) which is often cut off from the food supply by invading, embryo blighting, fungi; (i) stem end of grain.

Northwest produce grain of hard texture, more difficult to crush than some of the hardest Durum varieties when grown under moist earth and atmospheric conditions. Again, the Durum wheats (hard varieties) may make flour of high quality for bread making while the bread wheats, under certain conditions of growth and under certain lines of selection, may be very starchy in character, fit only for the production of low grade flour. The same variety may produce a hard berry of high gluten content, or a soft one of low gluten content, according to the cropping conditions.

If these statements are fairly accurate, many farmers sadly neglect the most important steps and the most important conditions for making high class grain for milling purposes.

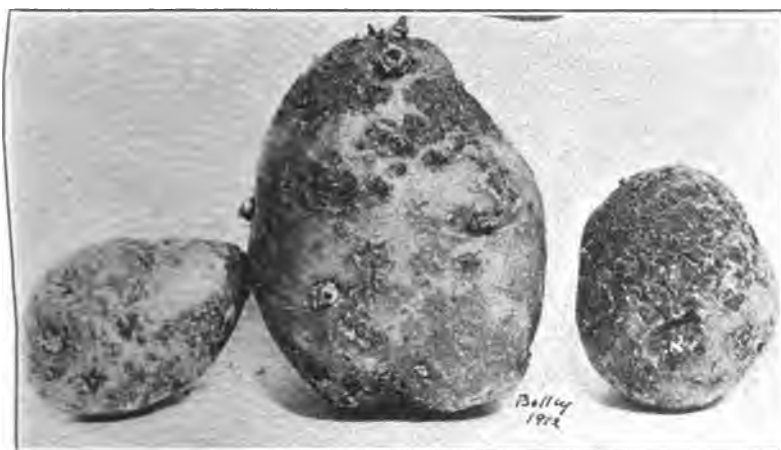


Fig. 5.—A Bad Case of Potato Scab. There was a time when potatoes were thus marked that writers said; "The soil is exhausted for potatoes." Since we have learned to properly select and disinfect the seed tubers and to disinfect the soil by proper crop rotation, one does not speak of such trouble as due to soil exhaustion.

New Varieties and Their Influence on Wheat Cropping:

There are now many varieties or selection strains within varieties which may be said to be "new" in agriculture. Unfortunately not all of these are valuable additions to commerce. Within late years there has been an intense desire on the part of farmers to try new varieties of grain and discard old ones,—a sort of craving to get something for nothing, and, as in commercial life, this has often resulted in loss. The farmer has thus often lost sight of the standard sort, has gained nothing of value in the new variety, and has failed to learn how to improve the old or any other variety.

So far as change of seed is concerned, if cropping to a new variety is practised in an intelligent manner, with a determination to give the variety a careful test, by keeping it separate and by improving it to its highest worth, there could be few words of disapproval, but no one can say too much or too



Fig. 6.—Corn smut. It is so apparent an infectious, parasitic disease that, when present, no one has a thought that the ground is worn out for corn.

harsh a thing against the constant trial of new varieties and the constant experimenting in the exchange of seed from soil to soil, if it is associated with no special effort toward improving a quality when once procured. No community ever made a success of any business, or in farming operations, when all of its individuals attempt to produce a different line or type of product. A community makes a success and a reputation for its goods because its members know how to produce goods of equal quality and uniform type, such as the market world knows and recognizes as of value. The whole community is benefited for the market looks to that community for that staple product. How can a wheat growing region, such as North Dakota, expect to hold its reputation for high grade wheat, if its individual farmers persist in hunting for a new variety every year, or persist in carelessly trying the seed that somebody else grew somewhere else? This method results in a mixing of varieties, strains and kinds and tends to deterioration of the value of the crop. The crop loses uniformity and qual-

ity, and as a living entity is subject to all of the ills of a mixed race. After years of experimental work, it is probably true that of all the so-called new wheats of the Northwest, there is not a single variety which exceeds the possibilities of the standard old-time Scotch Fife and Blue Stem wheats.

The records of the State Pure Seed Laboratory for the past four years show that it is essentially impossible to procure any large volume of seed of any variety of the wheats now grown within the state of North Dakota which is true to type. There is always a percentage of some other kind of wheat in the grain, due largely to the fact that farmers practice seed exchange rather than seed improvement and conduct no legitimate crop rotation. There can be no intelligent improvement of the kinds of wheat grown in a given community until the majority of the farmers there settle down to the growing of but a few types of grain, and unite in a common effort to improve the quality of these by selecting and grading all

Table No. III.—The Effect of Treated and Untreated Seed—Stooling and Head Formation on New Lands: Many plantings have been made upon virgin sod lands in which the top sod has been removed for the purpose of ascertaining the effect of disease upon the stooling and heading when planted on such clean land. All plants were planted an equal distance apart and upon the same day.

Variety of Wheat.—Durum, Arnautka. Seed of fair quality variously diseased. Table gives result from crop 1913 under very dry conditions, and is based upon use of 18 individual seeds in each case. (See Figs. 8, 10 and 18.)

Exp. No.	Condition of Seeds.	Average number of stools per plant.	Average number of heads per plant.
6	Seeds Untreated	9.66	6.66
1913 (Milbrath's Records).	Black pointed grains.	16.16	9.25
1913 (Milbrath's Records).	Pink colored grains.	6.9	3.6
1913 (Milbrath's Records).	Seeds purified by disinfecting with $HgCl_2$	21.7	14.0
1913 (Milbrath's Records).	Seeds Untreated	10.8	6.6

seed for sowing purposes. It is impossible, by means of fanning mills, to make any intelligent selection from a crop of wheat which is made up of two or three varieties. There can be no crop improvement under these conditions.

Susceptibility to Disease: Each particular variety has its own susceptibility to disease and its own peculiar period of ripening, each of which features may have a very definite and peculiar influence on the crop in a particular neighborhood. If farmers hope to escape the destructive influence of wheat diseases it will be quite necessary for most of them in a given

neighborhood to unite upon a single variety in order to get uniformity of growth with reference to its maturity. When several varieties are grown in the same community, some of the varieties are sure to be destructively attacked by disease and from such attacks great injuries come to surrounding fields of crop which ordinarily would not be so affected. For example, a variety which rusts very badly and matures early is apt to be very destructive to surrounding wheat which matures later, even though the late maturing variety may be of a type much more resistant to rust. Winter wheat crops interspersed among the fields of the spring crop act destructively upon the spring

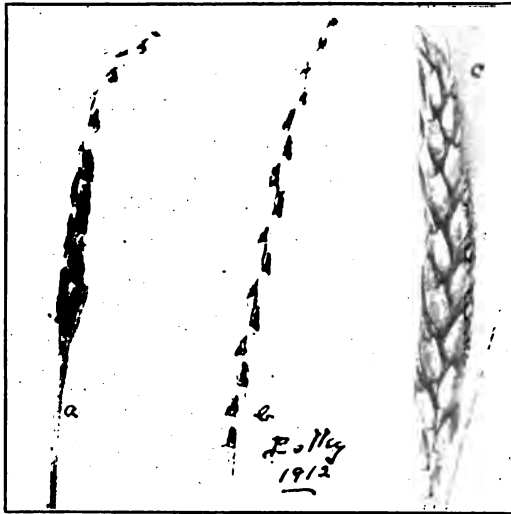


Fig. 7.—When loose smut of wheat, as shown in (a) and (b) takes all, one does not say the soil is exhausted for wheat but that an infectious disease transmitted thru the air and otherwise has caused the injury. When root-rots and seed blighting fungi cause the heads to fall to fill, as in the case of (c), and the grain to be badly shrivelled, as indicated in Figs. 1-3, many people have complained that "the soil is exhausted", "that its fertility has been used up", or that the climatic influences are bad, etc.

wheats for the reason that a general infection of various wheat diseases is brought upon the spring crop earlier than it otherwise would have to meet it. Winter wheat growing is antagonistic to spring wheat production in the same region.

Value of Home Grown Seed: In comparatively late years there have been separated from the main wheat types or forms a very large number of strains or varieties. These have been picked out by experimenters, and have been tried out by the farmers apparently more as a matter of curiosity than thru any consistent, purposeful, united effort to improve the yield or the

food value of the grain. These numerous modern varieties or strains indicate how very susceptible the wheat plant is to structural and physiological variations and indicate that it



Fig. 8.—This photograph shows typical heads of Flie wheat properly filled, grown on soil that has produced forty consecutive crops of wheat, but the soil and seed had been purified. The three blighted heads are typical of many heads which may be always found in wheat-sick soil, regardless of how fertile the soil is, or what the tillage. This lack of filling is not due to bad climatic conditions or to lack of fertility in the soil but to fungi which blight off the roots and prevent the seeds from being properly filled at heading time. The parasites penetrate into all parts of the straw and into the seeds of such heads before the seeds are mature, often cutting the maturing seed off from connection with the parent plant.

offers great hopes of improvement thru proper breeding and selection methods both as to seed production and seed value. One may readily hope to produce grain of greater milling worth according to the type of flour needed, and grains of much higher yielding capacity per acre thru proper adjustment and fixing of those varietal characteristics which most nearly tend to meet the local cropping conditions. It would seem to be possible

to meet the various difficulties of cultivation which arise because of peculiarities of soil, climate, disease and cropping conditions. The author is of firm belief that it will be possible to procure such varieties to meet any of these peculiar conditions. It should, however, be clearly understood that such varieties cannot continue to meet these conditions unless the

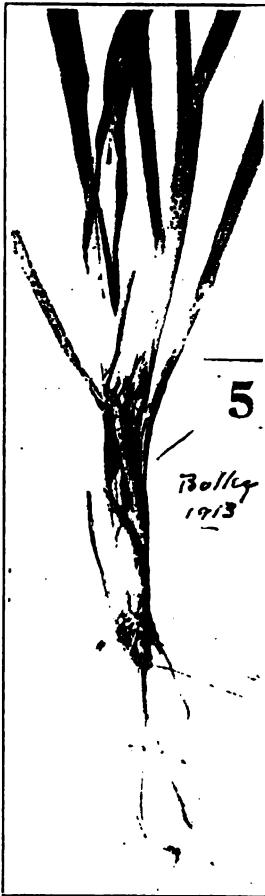


Fig. 9.—A typical young wheat plant from a wheat-sick area showing the lesions of root diseases attacking the plant at the point marked "5" just below the ground line where the plant came into contact with a piece of wheat stubble. Notice the essentially dead roots. Such plants early begin to show yellow and blighted leaves, commonly spoken of as "tip-burned" or "sun-scalded" plants. Such plants may be found more or less evenly distributed in the drill rows even in the first crop on the newest lands (virgin) of the west. When studied carefully, such primary crop or soil infection by the root diseases is usually found to be due to internally disease infected seeds. (See Figs. 1, 2, 3 and 13.) Sometimes, such primary infections are found to be due to other causes as adjoining diseased areas, droppings of cattle, disease bearing manures, etc.

persons who grow them under general cropping conditions recognize the manner in which the varieties were improved and also recognize the different methods which are necessary to maintain the qualities so obtained. If a farmer is not willing to select a particular variety of wheat from which to grow the main crop on his farm, and is not willing to grow his own seed

on his own ground, he can never be looked upon as a grower of wheat, as a breeder of shorthorn cattle is looked upon as a grower of high grade animals. Nor can he expect to reap the success that should naturally follow the hard work which is put upon the soil. There are no carefully planned experiments which have ever been made but show that home-grown seed wheat of the same breed is preferable for seeding there to that which has been grown upon other land;³ for, under proper culture, home-grown seed, year by year, becomes subject to certain natural conditions which act as selective agencies. There can be no hope of improving the quality or yield of wheat for a given neighborhood or wheat-growing territory unless the farmers recognize this important fact.

Table No. IV.—Possible Causes of Brown Spot, Stem Lesions of Wheat Near Ground Line: I introduce a report of D. G. Milbrath on the fungi present in the brown-spots or lesions at the ground line of maturing wheat stems, crop 1911. Specimens were obtained from Plots of the North Dakota Agricultural Experiment Station, from lands of the Movius Land Company of Lidgerwood, N. D., Adam Hass farm, and Titus Brothers farm at Edgeley, N. D., from material collected by H. L. Bolley at Kenmare, N. D., and by J. R. Campbell at Casselton, N. D.

"The brown spot is a creosote colored area on the main wheat stem. It is often an initial lesion or a continuation of an infection of the finer roots. The diseased portions were cut off, in about one-fourth inch lengths and dropped in formaldehyde of a strength of 3 parts in 1000 for approximately one minute. The cultures were made on Mannit agar, Lipman's formula. Cultures were made July 10th, 1911, and were stored at a temperature approximating 4 to 10°C. Examinations of cultures began October 5, 1911, and gave results as follows:

Total number of cultures	314
<i>Helminthosporium</i> , was present	268 times
<i>Alternaria</i> , was present	85 times
<i>Fusarium</i> , was present	42 times
<i>Colletotrichum</i> , was present	4 times

In many cases more than one of these parasitic fungi appear in a culture. For example, *Alternaria*, *Fusarium* or *Helminthosporium* were often associated in the same lesion. There were also other fungi which appeared in some of the cultures, the genus *Mucor* being quite commonly represented. The treatment accorded in this case was evidently not strong enough to eliminate all of the exterior saprophytic forms. In many cases nematodes were found living in the interior—even after this treatment. It is possible that after tissues of the culm are partly broken down that these worms may help greatly in weakening or injuring the wheat stem. In this series of cultures the genus *Colletotrichum* furnish comparatively few cultures. It is usually a habit of this fungus to grow higher up on the stem and sheathes." (See Figs. 9, 10 and 11.)

Modern Wheat Culture Conditions: Since the beginning of written history, it is apparent that the wheat crop has had periods of marked success in essentially all wheat growing regions. In this respect it is not unlike the flax crop. At first, wheat is grown in the various new regions into which it is introduced with quite uniform success. The cropping is usually remunerative under comparatively primitive methods, but the period of such success is usually comparatively short. On new lands or virgin lands, either newly upturned prairie sod or

3. Bulletin No. 17, N. D. Agricultural Experiment Station 1895, "Effect of Seed Exchange Upon the Culture of Wheat."

deforested lands, the yields usually are remunerative and the milling quality high. It is a matter of history that this period of high yield and high wheat quality on such new land areas has been limited to but a comparatively few years, after which

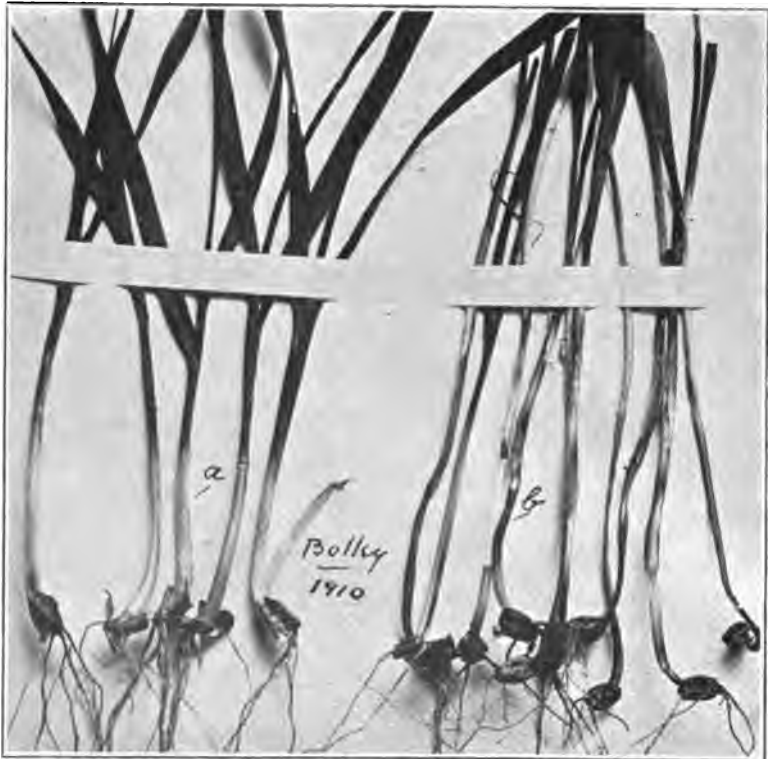


Fig. 10.—(a) Young wheat plants from purified seeds growing in new land; (b) young plants of the same age in the same soil from internal disease-infected seed. Notice the difference in the strength of the plants. Notice the white color below the ground line at (a) in the healthy plants. Notice the dark colored lesions of disease at (b) on the plants from the infected seed. Infected seed upon new land starts the trouble known as wheat deterioration under constant cropping.

both yield and quality rapidly fall. The crop has, in most countries, eventually largely given place to other crops under more remunerative and intensive cultivation. In a few countries the crop has held its place as one of the chief crops only because of intensive methods which far excel the work which is characteristic of the crop under new land agriculture. The United States, Russian, Argentine, Canadian and Australian areas, at present, illustrate this type of wheat cropping under new land agricultural conditions. Remunerative crops on vir-

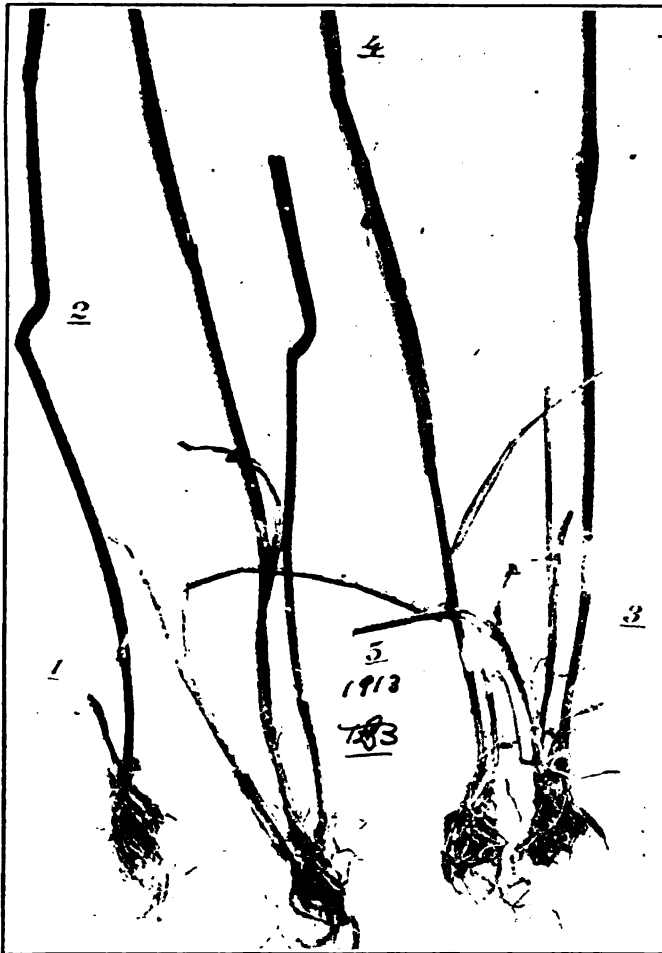


Fig. 11.—Stools of wheat taken from wheat-sick ground, Crop 1913, showing what I have called "crinkle joint" or "break-over disease." Notice the big swellings on the straw above the second joint and the crooks and dark markings. Notice also the blighted stools at the base of these plants and that the internodes and nodes near the ground are abnormally small. This is not an insect trouble as many have supposed but a fungus infection associated with weather conditions. The straw often finally breaking over as shown at (o) in Fig. 12. When wet weather follows a drouth in the early development of the straw, this trouble is pronounced on wheat-sick soils or in fields on which disease bearing seed is used.

gin soil may there be seen along side of poor unremunerative crops upon so-called "worn-out" lands due to general, extensive wheat culture.

The wheat lands of Germany, Holland, Belgium, England and France, represent, quite generally, remunerative wheat culture under intensive or improved cropping methods upon soil of long known wheat production. The length of time, therefore, under which a country's soil has been cropped to wheat and to its allied cereal crops is not to be considered a criterion as to the ability of that soil to produce. One must conclude

Table No. V.—Parasitic Fungi on the Interior of Nodes and Internodes: Table prepared by T. D. Beckwith from the crop of 1909 from a careful study of cultures obtained from two hundred nodes and internodes above the second joint of wheat which was in the dough stage of development, growing on wheat-sick soil, shows how commonly certain genera are present on the interior of the straw. Short sections of the node and internode were soaked for approximately one minute in formaldehyde of the strength of one part in a hundred. Mr. Beckwith's cultures on analysis showed the following results in percentages. In most cases the different genera were all associated in the same straws.

NODES.	
<i>Colletotrichum</i>	57.0
<i>Macrosporium</i>	53.5
<i>Helminthosporium</i>	40.5
<i>Fusarium</i>	33.5
INTERNODES.	
<i>Colletotrichum</i>	52.5
<i>Macrosporium</i>	33.0
<i>Helminthosporium</i>	34.5
<i>Fusarium</i>	27.5

As in Table No. VI Mr. Beckwith used the word "Macrosporium" to cover both the form *Alternaria* and *Macrosporium*. A type of *Alternaria* we have since found to be uniformly distributed throughout wheat growing districts and parasitically destructive on wheat at all ages and in all its parts. (See Figs. 11 to 15, inclusive.)

rather that production of the crop, both as to quality and quantity, is much more dependent upon climatic features, soil textures, and upon methods of cropping than upon special soil merit as to lasting fertility. If wheat once thrived well in virgin soil and climate, it is not likely that the soil may soon permanently lose the qualities essential to that crop. **So far as the history of cropping is concerned, the types of earth formation immediately underneath a wheat soil are of much more importance than the exact chemical fertility of the upper ten inches.** The surface soil areas may be modified by men thru cropping methods, but such modification for better or for worse, so far as fertility is concerned can only be temporary. The supplies of plant food from which the cropping area of the soil are renewable lie in the atmosphere, and in the earth layers beneath. It is thus hardly probable that any system of cropping will result in permanent deterioration, but there can be no doubt that under certain methods the immediate results may be quite dis-

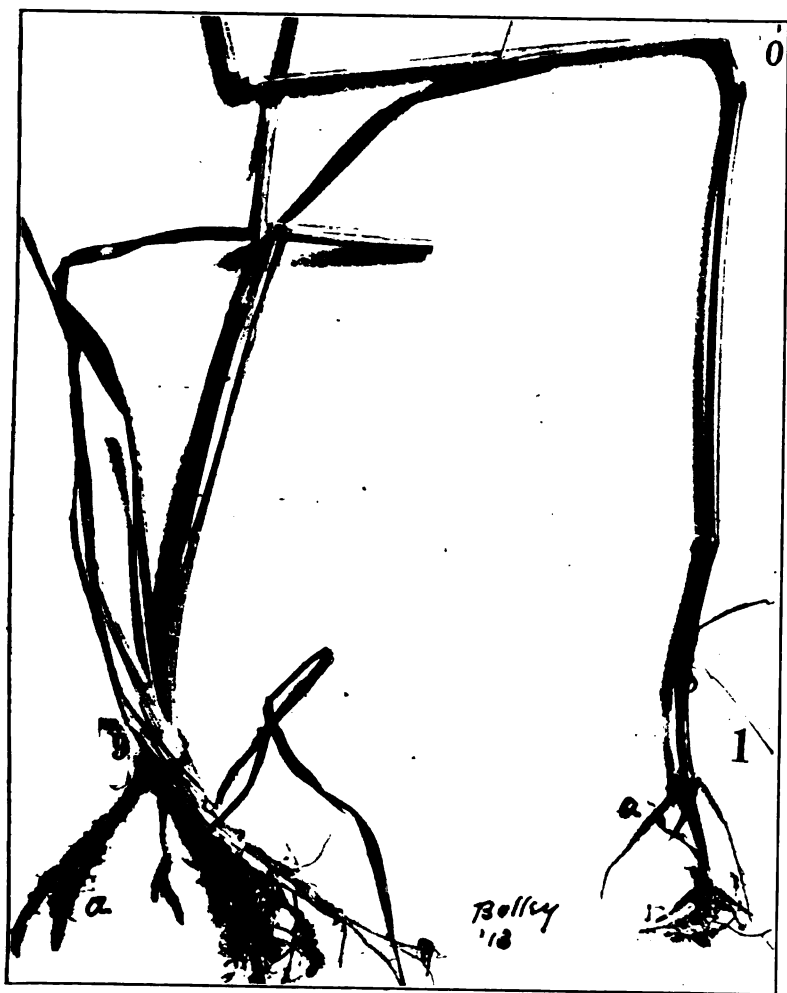


Fig. 12.—Typical straws showing break-over disease and peculiarities of the roots associated with lack of stooling. Notice at (a) the tendency to form roots above the ground line,—to re-root. This is due to the fact that the lower roots are blighted off by disease. When, after a severe drouth, a heavy rain falls, the heads shoot up rapidly, the straws enlarge and become ramified with the root fungi as shown at (a) Fig. 13, and finally break over as at (o), in this figure.

astrous. A cropping system, however, which is of such nature as to satisfactorily maintain the crop yields during the life of the men who are doing the cropping is not apt to injure the land for the following generation. It is, however, a well known fact that few farmers are able to keep up the yield and quality of cereals under a system of culture which calls for anything like a continuous, co-extensive, contiguous one-crop system over large areas.

Thus, it is evident that some regions of the earth may always be looked upon as in condition to furnish suitable remuneration thru wheat production when the methods of cropping are such as to provide for the health of the crop. This sum-

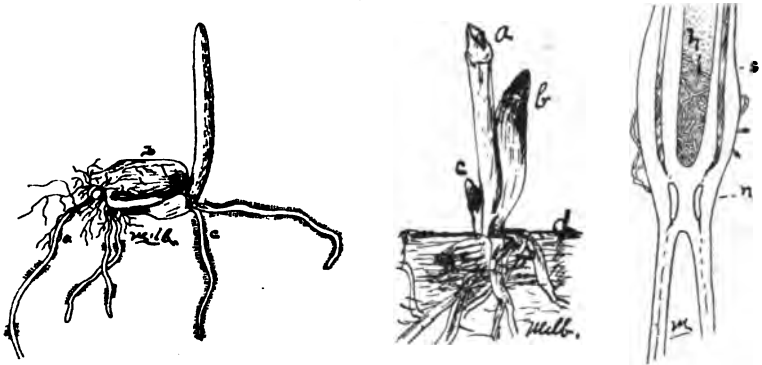


Fig. 13.—Sketches to illustrate special effects of root diseases. When an internally infected seed begins to germinate, its young stem and roots are attacked by filaments of mold-like fungi as shown at (a) and (b). Such a plant when it reaches the age of heading has many dead roots and attempts to re-root as shown in Fig. 12, and has many blighted stools that never develop as (b) and (c) of the middle figure. In the break-over disease the stems nearly always enlarge before breaking over. The bending or breaking over usually occurs just above a node at a point in which the fungi have thoroughly broken down the tissues and ramified the structure of the straw while it is soft or succulent, as at (h) in sketch marked "m". (Drawing by Milbrath).

marization would seem to be borne out by the history of wheat cropping. For those countries which, since written history, have produced and used wheat in the largest amount, and have shipped the greatest volume of wheat and allied cereal and forage crops into distant lands, including the animal life which has been reared upon such crops, are yet the producers of wheat in the most valuable and remunerative yields. It is hardly to be proved that these countries have ever added fertilizers to such lands, in the entirety, equivalent to that which they have drawn out of them. The writer is firmly of the belief that the present increased yields in such countries are more largely due to methods of seed selection, care of the seed and care of

the soil than to fertility added. Were it not so, agriculture would long since have bankrupted the best farms in the world for it is always the condensed products of the animal and plant life which are sold away from the land. The better the farming and larger the income to the owners, the more certain it is that the balance has always been against the land. This is not an argument against the use of every available means to increase the fertility of the soil, but I call attention to these matters that the reader may see how evident it is that there are some other constant factors which are more influential in the production of crops than mere soil fertility.

Wheat Deterioration on New Lands: Regardless of the foregoing discussion and ideas, it is a fact that American lands which are specifically suited to wheat cropping, when consecutively cropped to wheat, soon deteriorate in capacity to produce the crop both in yield and quality. Apparently only the soils of England and the most intensively cultivated lands of the old world are able to maintain a yield which may be said to be improving. Yet, I think, no one who is reasonably familiar with the lands of England, France, the Netherlands and Germany would contend that these are soils of natural texture and fertility exceeding those of the American plains and espe-

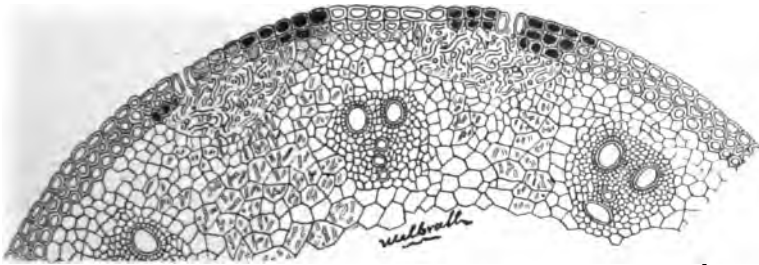


Fig. 14.—Cross section of wheat stem thru the second internode, showing location of points of attack on tissues by stem invading fungi which cause the break-over or crinkle-joint disease.

cially those of the Red River Valley of the North, or the wheat areas of Ohio, Indiana, Oklahoma and Kansas. Furthermore, it would seem to be impossible that the wheat crop, or any other series of crops, in rotation should in the matter of 5, 10, 20, or 40 years so reduce the fertility as to account for the deteriorated types of grain and yields which are represented by the twelve and a half bushel average crop for the best of these American areas. It is a strange fact also that American soils of texture and chemical quality comparable to each other have, in the history of the crop, not been comparable at all in regard to the speed with which they reach the condition in which they produce the average deteriorated crop. New wheat lands throught

the country, even under rough culture as to seed and tillage, have usually produced from 20 to 40 bushels of wheat of good quality. Some of these areas, under rather continuous cropping, have continued to produce 20 to 30 bushels per acre for periods exceeding twenty years while other areas of equal fertility and of similar chemical and physical texture have fallen to the low average of 10 to 15 bushels in but a few years—four or five of constant cropping.

Old World Areas Contrasted with New Land Areas: There are two or three features involved in the methods of agriculture of the old world and new world regions which may quite naturally account for the difference noticed in the crop returns. In the new land areas of America, there is no continuous or proper consistency with regard to crop rotation, and but poorly systematized methods of making use of farm fertilizers. This is true to such extent that the land of a given region, such as the Red River Valley of the North, or the wheat regions of

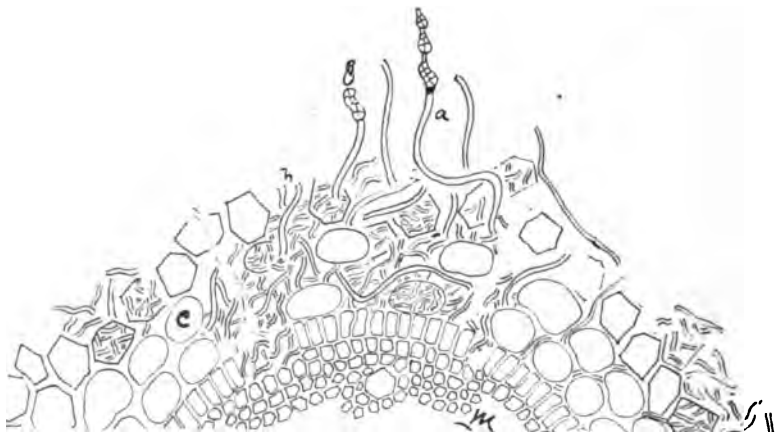


Fig. 15.—Sketch showing disorganization of the cellular portion of a wheat root as occasioned by one of the parasites commonly active in root destruction, Genus *Alternaria*. (Sketch by Milbrath.) Root destruction, as in the case of flax wilt, is chiefly occasioned by decortication near the point of attack.

Minnesota, Kansas and Oklahoma, may be said to be essentially under continuous wheat cultivation. The fields are so closely contiguous, continuous, and the time from crop to crop represents such slight intervals that the land may be said to have no rest from the crop and its influences; while in the wheat areas of England and of other wheat producing areas of the old world, farm practice is much more intensive and systematized. There is but slight tendency there to crop the land consecutively to the same crop. Long series rotations is the rule.

Individual fields are less continuous. There are many crops of variable type. Orchard and forest lands intervene, and artificial and farm made fertilizers are used systematically and quite intelligently as to the needs of each crop.

There are very good reasons why the two methods produce quite different results as to yield and crop quality, tho the actual soil fertility may be quite comparable.

Deterioration in Wheat Yields Due to Root-rots and Blight Producing Diseases: For a number of years the writer has been convinced, thru his observations and experiments, that the les-

Table No. VI. Effect of Different Methods of Fertilizing Wheat-sick soil or Purifying it on the Development of Wheat Stem Diseases, as Shown in Second Node and Internode. Crop 1909: The figures given represent percentages of times in which the various fungi appeared in the cultures. (Cultures and table by T. D. Beckwith; Table originally published in Twentieth Annual Report, North Dakota Experiment Station, with other data.)

Plot No.	Fertilizer Applied	NODE					INTERNODE				
		Colletotrichum	Macrosporium	Helmintosporium	Fusarium	Telento-spores	Colletotrichum	Macrosporium	Helmintosporium	Fusarium	Telento-spores.
1	Formaldehyde	100	60	70	70	20	50	20	50	20	10
2	Check	50	60	50	70	60	40	20	20	40	20
3	Bone flour	30	40	10	0	20	10	30	20	0	0
4	Rock phosphate	40	90	20	30	60	30	80	50	30	60
5	Potassium nitrate ..	30	80	20	50	50	30	60	20	30	50
6	Sodium nitrate	90	50	80	60	40	90	30	70	40	10
7	Kainit	30	20	50	20	10	30	20	50	60	20
8	Tankage	20	70	10	40	20	20	30	0	20	0
9	Potassium sulphate ..	30	60	50	10	30	30	70	30	30	10
10	Lime, air slaked and K ₂ SO ₄	20	40	50	10	40	20	20	20	0	0
11	Mixed	90	30	30	30	60	60	20	20	30	20
12	Ferrous sulphate	50	50	10	20	20	70	50	0	10	20
13	Red clover	50	70	70	40	40	50	50	70	20	0
14	Dried blood	90	60	100	60	40	90	20	100	60	0
15	Copper sulphate	60	40	20	0	10	50	10	40	0	10
16	Check	60	60	20	20	30	70	20	30	40	20
17	Compost	90	20	60	10	0	80	20	40	10	10
18	Check	70	40	30	50	30	80	20	40	40	10
19	Lime, air slaked	100	70	30	20	50	60	40	20	40	20
20	Sodium chloride	40	60	30	30	40	90	30	0	30	40
Averages		57	53.5	40.5	32	33.5	52.5	33	34.5	27.5	16.5

A study of this table indicates that no form of artificial fertilizing or soil treatment on which wheat will survive may be expected to eliminate the wheat-root and wheat-stem diseases without accompanying the work by seed treatment. However, the table indicates that some of the fertilizers reduced the attack of most of the fungi upon the nodes and internodes very materially as, for example, in the case of bone flour and phosphate. It must be also remembered that these are small plots surrounded on all sides by diseased grain and the benefits from certain soil treatments would probably be much greater on larger single areas. This table, associated with Table No. IV and Table No. V and numerous other similar analyses convinces us that the organisms found in the seed and found in the soil ramify all parts of the straw. (See Figures 10, 11, 12, 13, 14 and 15.)

NOTE: In this table Mr. Beckwith uses the word *Macrosporium* in a sense which covers both *Macrosporium* and *Alternaria*. Later investigations seem to indicate that *Macrosporium* is comparatively uncommon while *Alternaria* is the common form.



Fig. 16.—In order to conduct proper cross inoculation experiments it was necessary to ascertain some method of growing wheat plants or wheat seedlings free from root diseases. This work was undertaken in 1897 and in 1898 was perfected in such form as to make it possible to grow plants as shown in Fig. (1a) with pure white roots. Internally infected seedlings will not produce such roots even tho externally disinfected. Many normal appearing wheat seeds, as shown at (4a) never germinate because the embryo is killed. Notice the black-rooted wheat plant at (6). This seedling could not have produced normal wheat on any soil.

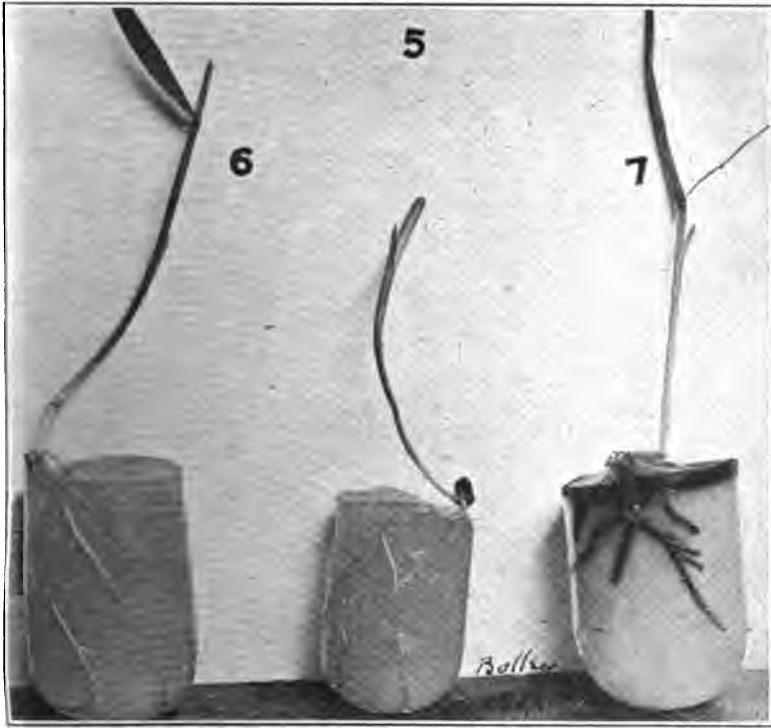


Fig. 17.—This work of seedling purification I believe to be original in its method. It has allowed us to tell with reasonable accuracy when a wheat or other cereal plantlet is free from disease, and thus allows of cross-inoculation with diseases of other plants. This figure shows at (6) a healthy wheat plant with white roots due to proper seed purification and growing in a special soil agar normally without the presence of any other organism; (5) a diseased wheat seed which was purified; (7) a grain of barley externally purified, but internally infected. Notice its blighted second leaf and black roots. (Cultures by Milbrath).

sened yields of wheat upon normally well cultivated but old wheat lands of the Red River Valley and various other spring wheat areas of the Northwest are not due wholly to soil deterioration as to available plant food.⁴

4. "The Use of the Centrifuge in Diagnosing Plant Diseases", 23d Annual Meeting, Society for the Promotion of Agricultural Science, 1902; See 13th Annual Report of N. D. Experiment Station 1903-07; Annual Report 1907, 20th Annual Report 1910; "Plans For Procuring Disease Resistant Crops", 28th Annual Meeting Society for the Promotion of Agricultural Science 1907; "Interpretations of Results Noted in Experiments Upon Cereal Cropping Methods After Soil Sterilization," Proceedings of American Society of Agronomy, Vol. 2, 1910; "Conservation of the Purity of Soils in Cereal Cropping," 5th Annual Dry Farming Congress at Spokane, Wash., Oct. 1910, Science Oct. 21, 1910; N. D. Agricultural College Experiment Station Press Bulletin 33; and North Dakota Agricultural College Experiment Station Bulletin 87.

It is, however, quite commonly asserted and has been the usual belief that such reduced yields should be largely attributed to a loss of humus and of available nitrogen in the soil, while some contend that phosphates, lime and various other mineral matters are either wanting or have been too largely removed by the constant cropping.

Our experiments, consisting of carefully planned plantings and pure culture experiments, under green-house and field conditions upon virgin soil and old wheat soils, covering a number of years, conducted for the purpose of trying out various ideas as to the cause of such deterioration, have each year given evidence that the gradually reduced yields and grain quality are not necessarily, directly associated with a deteriorated nitrogen condition, or other chemical deficiency, but are brought about primarily by specific crop diseases which are more or less affected by the characteristics of the soil and seed, and specifically by atmospheric conditions.

The results of these experiments are of such a nature as to show that the chief cause of the general deterioration of the yields of wheat on Red River Valley Lands, aside from such well known diseases as rusts and smuts, rests in the action of parasitic fungi, causing root-rots, and root blighting, and wilting and blighting of the straw and seeds, so that even on fertile lands the yield and quality of the seed may be reduced to such extent as to deceive one into believing that the land is worn out for wheat.

This is very important, and may well give much hope, for, if such losses are largely due to parasitic action and poor sanitary condition of soil and seed rather than to material losses in native fertility, possible remedies may lie in different lines of procedure than usually advocated. These experiments seem to furnish a material basis for the belief that proper handling of the

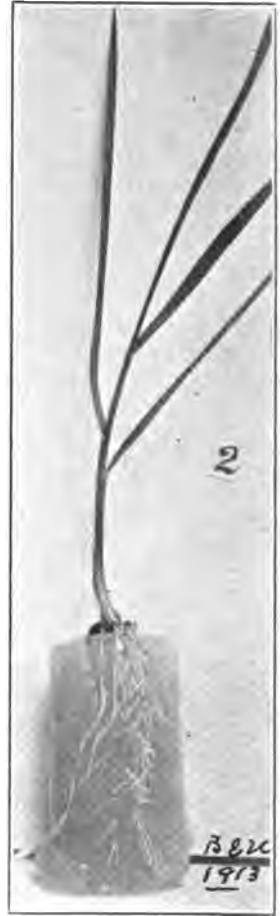


Fig. 18.—A normal healthy properly purified seedling wheat plant. Notice the sturdy stalk form of the plant and its pure white roots.

crop and soil for disease prevention may largely restore the yielding power of such soils without great cost.

Conditions as Observed: As previously affirmed⁵ (1) Continuous wheat cropping has been chiefly instrumental in the introduction of wheat parasites into the soil and into the seed. These parasites are carried in various ways from field to field and especially are transmitted from crop to crop by way of the seed, crop rubbish, etc.

(2) Thru the practice of continuous wheating, soils in many cases have become infected by from one to four or five definite parasitic fungi which attack after the same manner as the flax-wilt fungi attack and destroy the flax crop on old flax lands, and therefore such wheat lands may be said to be "wheat-sick" in exactly the same sense that old flax lands have previously been termed "flax-sick."

(3) Various types of fertilizers and chemical substances applied to the soil, and various methods of treating the soil, have a marked effect upon the type of injury that these fungi are able to accomplish. For example, by special treatments of such old "wheat-sick" lands we have been able to heighten the destructive effects of the diseases upon the crop. In certain other cases we have been able to greatly improve the character of the seed and straw produced.

(4) These diseases may attack the crop directly by way of the soil, or thru wind blown or water carried spores. In some cases the native sod lands are found to be already infected.

(5) The destruction of the crop so far as reducing the yield of plump seed is concerned, seems to be quite closely proportionate to the speed of maturity and to the hardness of the straw. A stiff, harsh straw suffers less than a soft succulent straw.

(6) While there is sufficient available fertility in most natural wheat soils to produce an abundant growth of straw, the quality of the straw produced is often of such nature that when attacked by the various soil and seed infesting fungi it is unable to resist and the grain fails to fill. Often the roots are destroyed and the young grains are cut off from the mother plant by the fungi before the milk stage is reached with the result that all of the grains of a head or most of them are shrivelled. The action of the fungi is greatly heightened by hot, moist weather and poor drainage. The fungi often attack the grain internally and usually fruit upon the straw, giving an ashy or grayish to smoky appearance on the upper portions and to the stubble after harvest.

5. See "Conservation of the Purity of the Soils and Cereal Cropping," Science October 21, 1910, and "Cereal Cropping", Science, August 22, 1913.

A Complex Problem: The problems involved in this sanitary question of soil and seed infection resulting in what has been termed crop deterioration and in the false belief that soils are worn out from continuous wheat cropping are of so complex a nature, and wheat cropping in the great plains of the West is of so widespread, continuous character that there will



Fig. 19.—When we found that seed grains, especially apparently normal wheat grains may be internally infected by the same fungi as are found in the straw and in the roots and in "tip-burned" and "sun-scalded" leaves, we took from the interior of such apparent normal grains pure cultures of the various fungi present. At (10) is shown a pure culture of a *Fusarium* which is often found internally in apparently healthy wheat grains and which causes the death of a large percentage of seedling wheat plants both on new and on old wheat cropped lands. In the new lands it is usually started by internally diseased shrivelled seeds. (Culture by Milbrath, 1911).

be great difficulty in accomplishing results in wheat culture comparable with that which has been accomplished under similar conditions with other crops. It has always been known that to grow potatoes on the same land for a number of years would result in small yield, scabby potatoes and rot. It was once

supposed that such grounds were worn out for potato culture. When, however, it was discovered that potato scab is an infectious disease, that the rots and blights are also transmissible from plant to plant and from soil to soil, it was soon learned that all such soils were not worn out for potatoes, but only disease infected. Now when the seed tubers are properly disinfected and the vines are properly sprayed and a reasonable crop rotation is maintained, an increase of crop at once occurs. But twenty-three years have passed since disinfection of potato tubers and potato vines was begun, and the average yield per acre for old land areas, once supposed nearly worthless has increased perhaps one hundred fold. It was easy to make this great improvement with the potato crop because of the rather small areas involved.

Again after it was discovered⁶ that the assertion that "flax is hard on land" is incorrect and that it is only disease infected land which causes such crop failure, due to the use of disease infected seed and to wind and water drifted spores, there have passed but a few years when one is able to see as large yields of flax grown upon old areas of previously so-called "worn-out" flax soils as were ever previously produced upon the same areas as new lands. With this knowledge, there is now every hope of making a great success in improving the flax crop because, as with potatoes, comparatively small areas are involved. The wheat crop, barley crop and oat crop involve much larger areas. Some of their diseases are interacting and it will be much more difficult for our farmers to make as rapid improvements in wheat cropping because of these facts. It can be done now that the chief reasons for seed selection, seed treatment and crop rotation are known to be principally matters of sanitation.

The experimental results at this station are of such direct nature as to warrant the statement that sanitary methods of soil culture and of seed treatment, similar to those advised for potato diseases and for the elimination of flax-wilt fungi from seed and from soil, will work wonders when applied to seed wheat and to the so-called "worn-out" wheat soils and will do much to bring future wheat crops up to the old time standards of stiff bright straw and plump grain. Present methods of agriculture must, however, be distinctly modified in certain specific features. There must be consistent rotation, planned with a view of eliminating accumulated fungi from the soil. When fertilizers are added, it must be done with an understanding of the needs of the crop. For example, a soil which con-

6. Bulletin 50, "Flax Wilt and Flax Sick Soil," N. D. Agricultural College Experiment Station, 1901, and Bulletin 55, 1908.

tains an excess of nitrogen as against phosphates, lime, potash and other mineral elements will produce a slowly ripening soft strawed grain which falls an easy prey to the root, straw and seed destroying fungi mentioned in this bulletin.

Previous to wheat culture, therefore, there should be such an adjustment of crops as to assure that the wheat crop which follows will not have an excess of available nitrogen, or provis-



Fig. 20.—A pure culture of one species of *Helminthosporium*, a root disease producing fungus which is transmitted both by the straw and seed and persists in the soil upon old straw and stubble. The fungus destroys much grain and causes much shrivelling of seed because of its action on the roots and lower stems.

ion should be made to add mineral fertilizers sufficient to bring about a balanced condition.

Explanations: This disease and sanitary theory explains many features with regard to reduced yields that were not previously open to explanation. For instance, it accounts for the fact that even new prairie lands, when now broken, often fail to produce plump wheat, accounts for the effect seen on over-

worked summer fallowed lands, or upon lands which have been rather lavishly manured with farm manures, and, in part, explains the evil effects of some crops and certain weeds which are carriers of disease. The action of the fungi is such that they gradually cause seed deterioration by internal attack, and even though new lands and properly worked old lands are wholly free from disease, disease infested seed sown there starts the troubles.

It is hoped that we may place this feature of so-called soil exhaustion and crop deterioration in a new light which will allow farmers to make great improvements in the cropping of this most important of all crops—wheat.

Table No. VII.—Comparison of Weights Necessary to Crush Wheat Grains from Healthy and Unhealthy Plants: Hundreds of tests have been made each year on the amount of weight necessary to crush individual grains of the various kinds of wheat grown on clean soil and grown on infected soil; grown on soils of different fertilizer applications, etc. I give here a table compiled from crushing tests for the year 1913 for two strains of wheat grown on disease free land, but from purified seedlings in contrast with infected seedlings, tested both on the clean land and on land which was infected by the application of dirt from a wheat-sick field.

Bed.	Row.	Kind of wheat.	Treatment	Kind of Soil	Crushing Weight of Grains in grams.
13	1	Durum	Seedlings Agar Purified	Clean	19,577
12	1	Durum	Seedlings Infected	Clean	18,575
15	8	Durum	Seedlings Agar Purified	Diseased	19,295
3	1	Fife	Agar purified seedlings ..	Clean	10,247
3	7	Fife	Plants Inoculated	Clean	9,575
15	2	Fife	Seedlings Agar Purified	Diseased	9,252

The crushing weights in grams as given in table are averages of results from twenty most normal grains. By an examination of these figures it will be seen that the root infected plants were unable to produce seed of as high crushing resistance as those which grew from the white rooted Agar purified seedlings on clean soil. (See Figs. 16, 17, 18.)

Symptoms of Deterioration as Noted in Soil and Seed: The history of wheat cropping shows that at first new lands yield bounteously in quantity and quality, but in a comparatively few years an evident deterioration of the seed produced sets in. The fall in bushelage per acre is not more marked or more rapid than the deterioration in quality as to plumpness of grain, flour content, hardness, color and other characteristics. By almost common consent, many agriculturists, chemists, biologists millers and farmers have assumed, when such conditions of the crop arises after more or less continuous cropping to wheat and other cereals, that the lands have "deteriorated."

The symptoms as observed in the slow growth of the crop, the dying out of young plants, the blighting, "tip-burning," "sun scalding" and discoloration of the young plants, the weak-

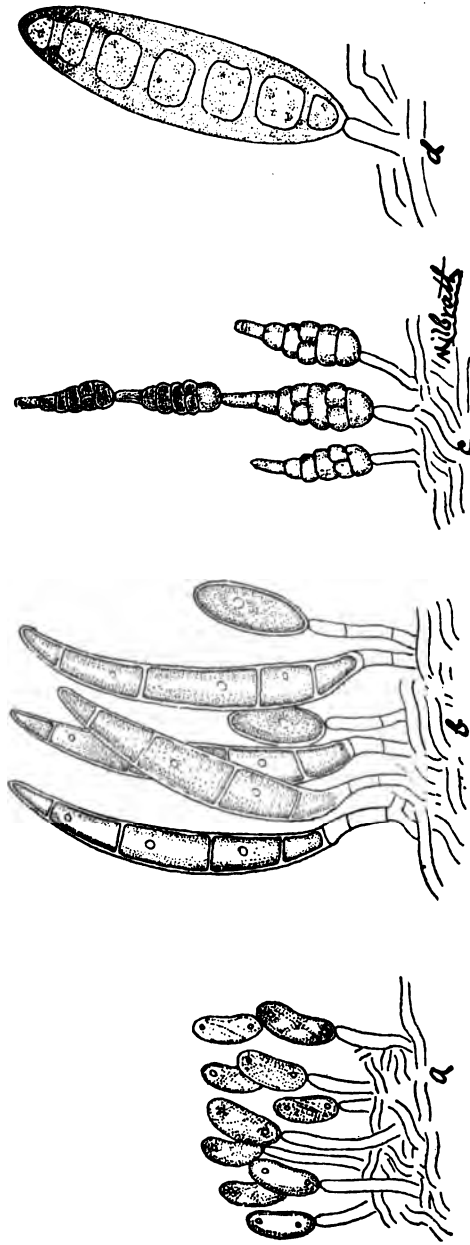


Fig. 21.—Sketches of characteristic spores of certain of the wheat-root and wheat seed destroying fungi: (a) Spores of one species or strain of *Colletotrichum* which usually does most damage by causing premature hardening of the lower stems or nodes and internodes; (b) Spores of one of three or four species of *Fusarium* which are root, straw and grain invaders; (c) Spores of a form of *Alternaria* which decorticates wheat roots and invades the heads and bran layers of wheat; (d) a rough sketch of a type spore of one of the wheat-root destroying species of *Helminthosporium*.

ness of the straw, the shrivelled seed, the common deficiency in proteid content of the grain have all been taken as indicating improper food relations.

I think I am safe in saying that it has been quite commonly assumed that lost nitrogen, phosphate, lime or other plant food deficiencies in the soil are to be expected under such cropping conditions. Furthermore, chemists, as they measure availability of plant food, have found that such old soils often show more or less change in the available plant food. The writer, knowing as he does that a wheat plant can extract essentially all of the available material of a particular food element from the soil before showing noticeable change in its growth relations has always doubted that the general conclusions of soil deterioration under such cropping conditions is justifiable; for there are many fertile soils which fail to produce normal wheat, and there are some very poor weak soils which produce nice, properly colored milling wheat. These, so-called, deteriorated wheat soils also produce high yields and quality in other crops.

The symptoms with regard to crop and soil relations on wheat-sick areas are interesting and, in part, show the complex nature of the problem. It should be remembered that there are many types of soil in the various wheat regions and that the writer is not contending that there are not some soils which are deficient in certain plant food elements to such extent that a normal yield of wheat can not be expected. The symptoms and crop characteristics here stated are for soil regions which are recognized as wheat producing regions,—soils which once produced heavy crops of wheat but under present conditions cannot be relied upon to produce wheat of normal form, except under years of exceptional conditions and under methods of exceptional nature, yet do produce other crops in high excellence. We refer to lands which once produced exceptionally good wheat crops, yet in a short time of comparatively constant cropping to cereals have been reduced to a condition in which agricultural methods, as now practised, including best recommended methods of crop rotation and soil fertilization, cannot be relied upon to produce a crop that could be considered normally equal to that which the new lands gave. Some years, certain old lands, have been known to produce crops even excelling in yield anything previously produced though neither the owner nor any educator could explain such strange action of soils supposedly "deteriorated by overcropping." In the Red River Valley of the North where wheat has been a general crop for from thirty to forty years, where the fertility of the land is not questioned with regard to its capability of producing any other crop except only flax, and where chemical analyses yet show a high grade of soil fertility, the fact remains

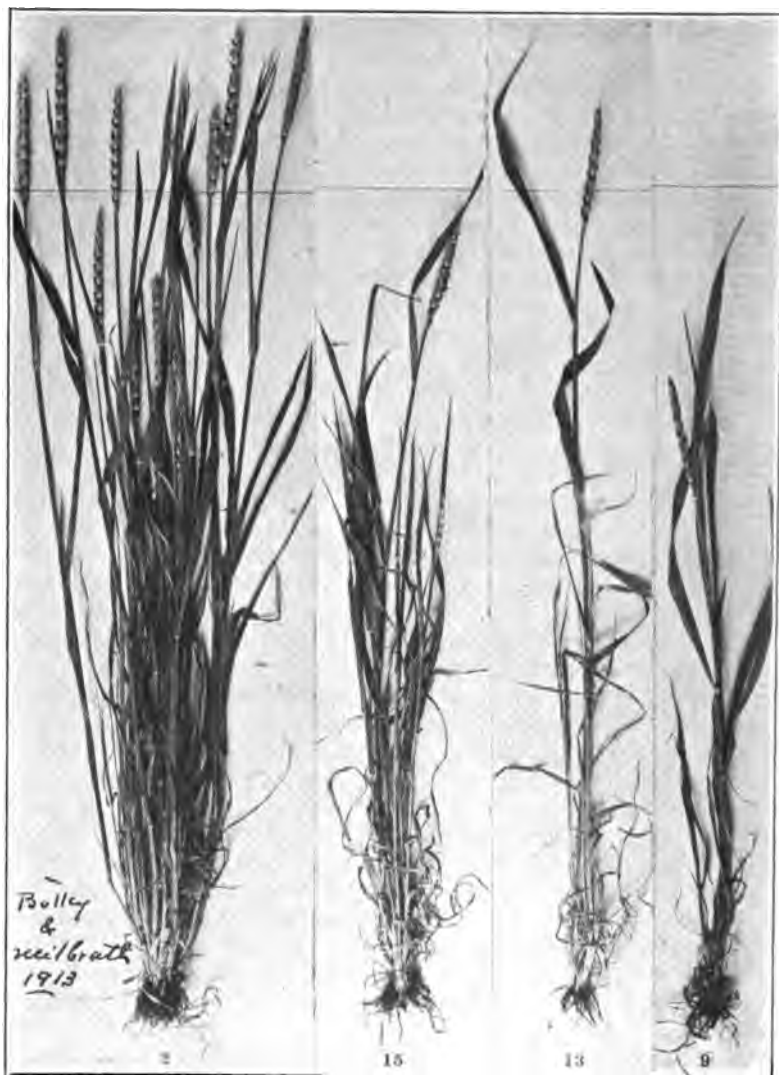


Fig. 22.—When we were able to procure pure cultures of the fungi and also to produce disease free seedlings, we were ready for inoculation experiments in the field to test the effectiveness of such parasites upon the development or retardation of the crop. The plants in this photograph show the relative growth made on the same virgin soil from planting of wheat seeds of the same weight and strength from the same parent head, planted on the same day; (2) Growth from agar purified seedling; (15) Growth from unpurified seedling; (13) Growth from seedling which was inoculated by a mixture of spores from pure cultures of *Fusarium*, *Helminthosporium*, *Alternaria* and *Colletotrichum*, all taken from the interior of what appeared to be normal wheat grains; (9) Comparative growth from the same strength of seed made on virgin soil when inoculated with dirt and stubble from wheat-sick land. (See Figs. 17, 18, 21, 28 and 24.)

that the wheat crop on such old wheat cropped soils, cannot be relied upon to give anything like uniform seed quality from the most consistent systems of cropping by whomever recommended. It is usually recognized that a well worked corn ground makes a seed bed thoroughly satisfactory for the production of a spring wheat crop, yet on lands apparently exactly similar as to age, content, texture and drainage, one man may produce a crop of thoroughly shrivelled grain, worthless straw and light seed, while a neighbor, under exactly similar conditions as to tillage and date of seeding, produces a reasonably good yield of seed. Thus while it is usually recommended that corn cultivation best prepares the ground for wheat, many farmers, by their experience, are convinced that often all they can expect from such extra work is what they would designate as "too much straw and shrivelled seed."

Similar results have been observed upon well worked summer fallowed lands. Chemists and agriculturists have been prone to explain that the farmer, by overworking the land, produced too much available fertility, especially in the nitrate form. This causes the farmer no little worry because he has been doing the cultivation act, as he understands it, for the purpose of providing more available fertility, saving moisture, etc.

Many farmers, thinking that continuous cropping to wheat has tended to remove the nitrogen content of the soil, have spread fresh barn-yard manures upon wheat stubble lands or have top-dressed lands previous to wheat culture, using the manure spreaders. Some have reported good results from this in bushelage. Others, after the application of a very slight amount of fresh manure, have reported very disastrous results in the nature of soft, over-grown straw and shrivelled off-grade grain. Clearly, if the land were impoverished as to humus and nitrogen content, due to wheat cropping, barn-yard manures ought to be beneficial, yet, in many cases, the application has injured the wheat.

Peculiarities of Crop on New Lands: Native sod lands that have been a long time in pasture are often plowed up with the hope that a big yield of fine grain can be taken, but the result, as in the case of so-called "over-worked summer fallow," or corn ground, is as likely to be a failure as a success. Fully as many people report over-growth of straw and shrivelled grain as report increased crops of good quality.

New or virgin lands remaining in the wheat belt unplowed, even though they represent select areas of land, when plowed and sowed to wheat, under present conditions, cannot now as in the early days be relied upon to produce the quality of wheat then produced on immediately adjacent lands. As often as

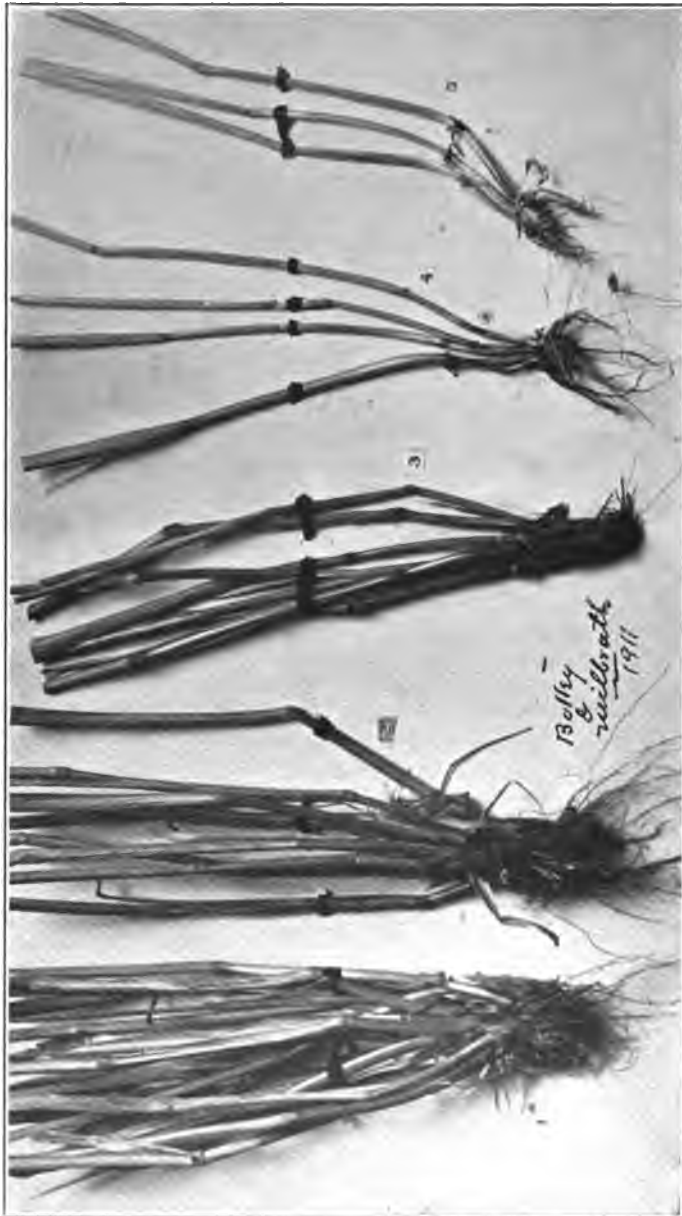


Fig. 23.—Comparative growth from normal wheat grains from same parent. The seeds were all of the same weight. All were planted equally distant apart on same day. (1) This plant represents the average growth of 200 plantings from properly agar purified seedlings—white-rooted plants on clean soil, see Fig. 18; (2) a typical plant of average stooling from seedlings purified by the "sandpan selection method"; (3) average growth and typical plant from unpurified seedling; (4) typical plant of average stooling when inoculated with a mixture of spores of wheat-root destroying fungi; (5) typical plant and approximate average stooling from like seeds, as in (1), (2) and (3), showing the growth on virgin soil inoculated with dirt from wheat-sick soil. Compare results with same numbers in Fig. 24.

otherwise, the crop is apt to produce light weight, off-colored, "spotted," "white bellied," "black-pointed," "pie bald," shrivelled grain upon a rag-like, light weight straw. Because of these facts, many of our most able old-time wheat growers have been inclined to contend that there must have occurred changes in climatic conditions. No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years. These lands certainly are as fertile as the adjacent areas which were broken in the early days of wheat culture.

Table No. VIII. Comparative Growth from Properly Purified Wheat Seedlings Contrasted with Unpurified Wheat Seedlings and Specifically Inoculated Seedlings: The table is based upon 200 plantings of pure bred Fife Wheat. The seeds were planted on the same day on new land and the crop was harvested on the same day. Crop 1911. See Figures 23 and 24. We have similar tables constructed for almost all varieties of wheat that grow in the Northwest and for the years 1911, '12 and '13. Practically all of them bear out the conclusions which this table on inspection must indicate.

Seed Used.		Average No. of stools produced per plant.	Average No. of heads produced per plant.	Average weight of seed produced per plant in grams.
I.	Agar purified Seedlings	17.24	11.07	21.8
II.	Seedlings purified by selection from germination pan	11.2	7.9	11.8
III.	Untreated seedlings.	8.5	6.11	4.72
IV.	Purified seedlings, afterwards inoculated	7.55	5.95	4.32
V.	Internally diseased seedlings	7.6	3.5	3.

It can be seen at a glance that these present new lands are now subject to wheat diseases coming thru poor seed and by dust and dirt from the adjacent old worked wheat lands.

Peculiarities on Old Cropped Lands: On areas where wheat has been grown continuously there is a tendency for the crop at first to produce a heavy growth of foliage and to show great unevenness of growth throughout the field, even though no unevenness of ground, peculiarities of chemical constituents, of drainage or of methods of culture may be observed. Some areas may yield fifteen to twenty-five bushels per acre, while others immediately adjoining, of the same day's seeding, may scarcely be fit to cut. Straw often varies in height on such areas from a few inches to a foot or more, and shows great variation in color and texture throughout the season.

The grain from such crops is uneven as to grade, apt to be shrivelled and light weight per bushel, and off in color regardless though the greatest care is taken in harvesting. In

addition to these peculiarities, which are common to wheat regions throughout the United States but particularly pronounced in spring wheat regions of the Northwest where the work is conducted on such an extensive scale that one to two-thirds of



Fig. 24.—This photograph shows the products in seed produced by individual plants, the stubble of which are photographed in Fig. 23. The seed well represents the comparative productiveness of proper seedling purification as compared with the growth under unsanitary conditions as represented by internally infected seed or disease infected soil. (See table No. 7. by Milbrath.)

all the land may be said to be in wheat. Farmers have always complained of many features with regard to the wheat crop and other cereal crops for which it has been difficult for anybody to account. Generally the shrivelling has been attributed to many causes, among the most common of which are: (1) Hot winds drying up the soil and drying out the straw; (2) "Sun-scald" and hot winds in the presence of too much moisture in the soil; (3) Excess of moisture in the atmosphere and hot sunshine resulting in "sun-scald" of the heads at the blossom period or at the time the grain is setting; (4) Shallow tillage; (5) Finally, by some, that too heavy a growth of straw and grain sets in proportion to the moisture and fertility available. One often hears such expressions as: "There is heavy enough stand for a crop of 25 bushels, but on account of the lack of fertility and moisture the grain will not be able to fill more than ten or twelve bushels."

Approaching more directly the point of symptoms, it is a matter familiar to everyone to hear farmers talk about "sun-scald" and "tip-burn" even when the wheat plants are but a

few inches high. When asked what is meant, they explain that the wheat has made too rapid a first growth and the "atmospheric conditions are bad" the young leaves turn yellow and blight and die because of the intensity of the sun action on the delicate plants.

Just preceding maturing time, a great cry goes up which says, essentially, the heads are large and the grains seem to be set in all of the rows of the spiklets but the "upper third or half is not filling." Every man seems to have a different opinion as to the reason for this. Some blame it to the lack of strength in the land, others say it is due to the moisture in the atmosphere or "sun-scalding" the young blossoms or wheat grains just as they set or form. Others attribute the whole trouble to rust or smut, assuming that these diseases have become more and more destructive. Others, more observing, report that the shrivelling goes on even though the straw is not rusted or smutted. It is apparent to most observers that wheat rust is naturally much more destructive on the old wheat lands than on the new.

There are exceptions to all of these conditions, and these are often located in neighborhoods in which the most destruction is accomplished. Many are hard to explain on the basis of any ideas laid down by chemical analyses or by experts in crop rotation or in the physics of the soil as represented in drainage and manuring methods. It is admitted that there are certain types of crop rotation which when constantly followed tend quite commonly to produce paying yields of wheat or other cereals, and it is quite agreed by agriculturists, chemists and plant physiologists that certain methods of fertilizing soil tend to improve the crop as shown by the averages for a number of years, yet the fact remains that, under normal weather conditions, the wheat crop in such old wheat regions is not reasonably certain to give grain quality under the best known cropping methods.

Often the lands, under apparently the most rational crop rotations produce wheat of so poor a quality that one can in no wise account for the results. It can be said with truth regarding such old wheat land areas that fertile soils, sufficient rain fall, and such methods of rotation and of soil fertilization, as heretofore known have not regularly been found to give better results than adjacent fields under general methods of agriculture.

Not a few farmers complain that to add barnyard manures to their wheat lands is but to increase the growth of straw, lessen the yield of grain and reduce the grade. In the various farmers' institutes of the cereal producing states, one has often heard farmers complain that they no longer are able to pro-



Fig. 25.—Effect of seed inoculation by means of pure culture of wheat-root fungi. The wheat is known as "Huron". The seed weighed over sixty-three pounds per bushel and was of high uniform hard quality. It was seeded in equally prepared beds on lands uncropped to wheat for 18 years. The bundles represent an equal number of seeds planted and same area of ground. The seeds were inoculated by dipping into distilled water which contained the spores of pure cultures as follows: (5) *Uninoculated*; (7) *Helminthosporium*; (4) *Fusarium*; (6) *Alternaria*. The photo gives a fair comparative idea of the destructiveness of these root destroying fungi. Two other species not commonly found in our work resulted in practical destruction of the seedling plants. (Cultures by Milbrath.)

duce wheat of the quality once produced, though they now work the land much more carefully, having better machinery. The author has made a careful study of this matter and is convinced that it is true that the land is now better worked than ever. Some of the farmers practise essentially all of the doctrines which the experiment stations and farmers' institutes are able to carry to them, yet reap low grade wheat and cereals upon lands which produce abundantly in crops of non-cereal type. When the farmers have asked what is the matter, they have been told about as follows: "You cannot expect to continue reaping grain of high quality." "Your constant methods of cropping have deteriorated your soil." "You have lessened the nitrogen." "You have interfered with the humus content." "You have withdrawn much phosphate, lime or potash," as the case might seem in the mind of the particular man answering the question. The farmer asks "what shall we do?" The answer has been: "Rotate, raise stock, plant corn, cultivate." "Clear your fields from weeds." "Select your seed," etc. Yet it may truthfully be said that many able farmers who are doing most of these things on land of known high chemical fertility and fine physical texture, yet reap twelve and a half to fifteen bushels of shrivelled wheat where but few years since they took twenty-five to thirty bushels of sixty to sixty-four pound stuff. Men who thus strive have naturally lost much faith in the doctrines of the conservation of the fertility of the soil and in the doctrines of the necessity of crop rotation. Often the best rotation gives the most shrivelled grain and this we, as educators, have been utterly at a loss to explain, except only to refer to "rust," "sun-scald," "poor drainage," and many imaginary things that might prevent a plant from yielding. One of the conditions of wheat cropping, which at first sight is the most discouraging one, rests in the observed fact that when the climatic conditions, soil conditions and harvesting conditions have been most propitious for the development of the wheat, often the yield has been of the most inferior type of seed. Though the bushels of grain and tons of straw may at times be somewhat larger, the quality is so inferior as to be no longer recognized as in the class for which the Northwestern wheat regions were once noted.

The Cause of Deterioration: The writer has, by his experience, and thru the aid of many assistants, conducted experiments and observations extending over a number of years which convinced him that it is perfectly safe to affirm that our old wheat soils are sick throughout or sick in part in large areas in exactly the same sense as certain cotton lands are sick with root rots, in the same sense as certain melon lands produce root-rot and blight; in the same sense as old potato lands pro-

duce rot and scab; in the same sense as the Germans recognize when they speak of flax being a bad crop because it produces Bodenmuedigkeit, "flax-tired" conditions. It is now possible



Fig. 26.—A pair of a series of pot experiments which have been conducted under green house conditions. The pots were each seeded with five grains of wheat. The soil was made up of pure crushed quartz.

Plant food was furnished as a nutrient solution made by soaking a standard amount of soil for 24 hours in a given volume of distilled water. (9) shows the growth when the solution was from virgin prairie soil. Pot 2 shows the growth when the plants were watered with a solution taken from wheat-sick soil unfiltered. When, however, the solutions furnished by wheat-sick soils were sterilized or purified, the growths were always approximately equal to that in nine. Numerous experiments of this nature corroborate all of our field plot work and will be published in another bulletin.

to recognize such wheat-sick areas and map them as well as one could by a study of the flax crop or its stubble, map flax-sick areas for wilt or flax canker.

This mapping of the sick areas can be done at any time from the time the wheat plants first come out of the ground to the time the stubble is plowed in the fall. The diseases can be detected in the soil by many methods. The diseases can now

be recognized in the crop by the symptoms and by pure culture methods. They can be proven to be destructive by the most exacting methods of the histologist and of bacteriologist. The problem is a complex one because there are more diseases than one which live in the soil and are transmitted from crop to crop, and because there are many varied ways of transmission. Any one of several distinct organisms, which in years past have been looked upon as simple decay forms, molds, is capable of placing the land in an unsanitary condition for the crop of wheat, to such extent that a profitable crop cannot be grown there when the land is once infected. These various and sundry

Table No. IX. Contrast between the weight of Crops Grown on Steamed Wheat-sick Soil and on Unsteamed Wheat-sick Soil, from Purified and Unpurified Seedlings. (Crop 1913, Bed 1, Plot 32.)

Row.	Kind of Seed.	Soil Treatment	Seed Treatment	Weight of Straw and Grain. Grams.	Weight of Grain. Grams.
4	Fife	Steamed	Selection from Germination pan.	410	147
4	Fife	Unsteamed	Seed untreated	165	47
6	Fife	Steamed	Seedlings, Agar purified	315	95
6	Fife	Unsteamed	Seed untreated	107	51
7	Fife	Steamed	Seedlings, Agar purified	325	77
7	Fife	Unsteamed	Seed untreated	195	35
13	Marquis	Steamed	Seedlings, Agar purified	338	147
13	Marquis	Unsteamed	Seed untreated	185	65
14	Marquis	Steamed	Seedlings Agar purified	326	87
14	Marquis	Unsteamed	Seed untreated	161	35
22	Marquis	Steamed	Seed untreated	275	114
22	Marquis	Unsteamed	Seed untreated	230	95
19	Fife	Steamed	Seed untreated	159	328
19	Fife	Unsteamed	Seed untreated	81	15

NOTE: In this experiment the seedling plants for each row were transplanted into and across equally prepared seed beds, one steamed and the other unsteamed. Each pair as numbered were planted on the same day. The seeds for each pair were exactly of the same breed or strain and the individual seeds before being germinated were selected for highest color, hardness, and wheat quality and as to uniformity of weight and size. The differences in yield, therefore, must be chiefly attributed to the changes in the ground due to steaming as shown in Figure 29, associated with changes in the seed due to seedling purification. Notice, for example, the marked differences shown in the yields of straw and grain, in Rows numbered 4 and Rows numbered 13. There were something over four times as many plantings on this particular bed as are indicated in this table but all of the figures bear out the same conclusion as above. (See also Figs. 26 to 30.)

wheat disease producing fungi are not only transmissible from crop to crop, but persist in the soil from year to year, necessitating rigid methods of cropping in order to retrieve the soil for wheat culture. They do a greater or less amount of damage according to the kinds of soil and atmospheric conditions. They are so parasitic in nature that they persist in their destructive work in any type of soil in which the wheat plant can thrive, and they are so nearly saprophytic in their habits that they exist as decay forms on decaying roots, stubble and upon the humus of the soil or in yard manures, and are thus readily

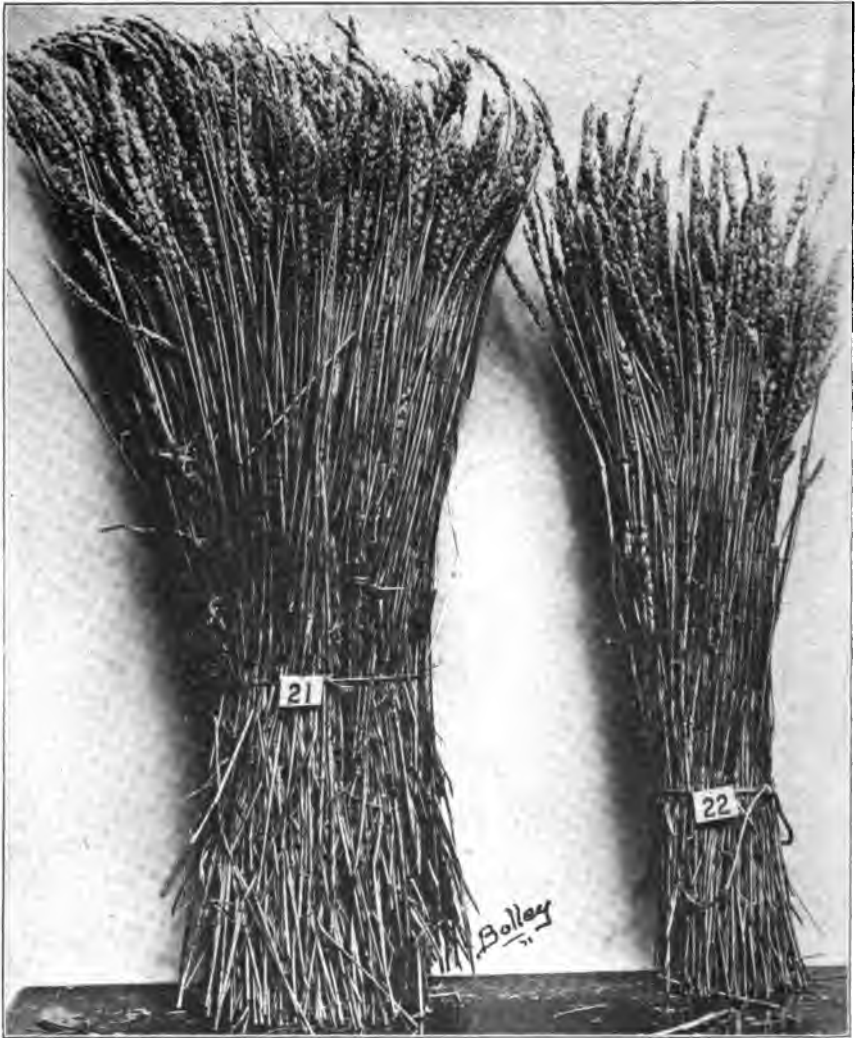


Fig. 27.—Comparative crop of Scotch Fife wheat upon two equal contiguous areas of Red River Valley soil on which there had been approximately 40 consecutive crops of wheat. The seeds were the same as to kind, weight, and number; and the date of planting was the same. Bundle 21 grew on an area of ground which was steam-sterilized for a depth of 14-inches during the spring of 1905. The steamed plat, for five years, raised a much heavier crop each year than the check plats, although the land was handled in exactly the same way otherwise. Bundle 21 is the fifth crop on the land since it was purified by steaming, Bundle 22, the check.

distributed from crop to crop and from field to field. They are so parasitic that thru their internal connection with the seed, their distribution from country to country and from field to field is made easy. They are world wide in distribution and vary in destruction according to method of cropping. Our survey of these troubles extends specifically over North Dakota, large areas of Alberta, Saskatchewan, Manitoba, Minnesota, South Dakota, Washington, Indiana, Kentucky, New York, Ontario, and by means of seed, we have found that they are not uncommon to England, Russia, France, Algiers, Australia, and other wheat growing regions. Not only are they able to live in the soil, but they can attack the wheat plant in all its parts—roots, stems, nodes, flowering parts and mature seeds. It may thus be said that in this announcement, we are discussing a soil factor and a feature of crop destruction which is of no local nature. We can now take any type of soil, new or old as to the growth of wheat, and from it can raise either a typically diseased crop or plants of normal growth. We can take the best pieces of land that any man can furnish and with slight application of either pure cultures or old diseased wheat straw, or wheat seeds fix that soil to such extent that no form of ordinary culture can raise a normal crop of wheat.

New lands can be made, by inoculation with infectious matter, essentially sterile for wheat, but again, by methods of purification, whether chemical or otherwise, the same soil can be made to produce normal wheat from normal seed. We have conducted persistent cropping experiments with many different pure, pedigreed strains of wheat upon many separate plots of land, handled and treated in many separate ways, and all of these experiments lead to the same conclusion, namely: that in the presence of certain root diseases of wheat and other cereal grains no one is in position to draw any reliable conclusions as to what quality of crop may be caused to develop in a particular year upon a particular piece of land under a particular method of cropping. These experiments indicate clearly that rotation of crops have much to do with the possibility of raising a normal crop. They show that certain methods of handling fertilizers have beneficial effects and that other methods of fertilizing, which, ordinarily, are deemed very appropriate, are very destructive in the presence of these diseases. These experiments in association with this new knowledge with regard to wheat diseases also explain many anomalies of cropping which heretofore have been inexplicable.

Unsanitary methods of handling the soil, the crop and the seed, and the existence of wheat and other cereal-sick soils, with the existence of internally diseased seed taken together, represent a constant factor which has in years past acted to

vitiating the conclusions of many well-planned experiments in crop rotation and soil fertilization.

The foregoing statements as to the status of wheat and cereal cropping in which we have outlined the peculiar symptoms existing in large areas and regions of wheat cropping may be viewed in a somewhat better light by a consideration of more specific features or symptoms, associated with statements as to what they may indicate.

Specific Symptoms: In regions of general wheat culture, farmers complain that year by year more seed must be sowed in order to maintain a stand or a normal yield. Once a bushel



Fig. 28.—A view of a portion of a rod square of ground which was steamed with live steam to a depth of 14 inches in the spring of 1905. See Fig. 27. The portions on the right indicate the continuation of the plot on what is known as "rotation plot I", a plot under continuous wheat cropping and known as a "wheat-sick area". For the first three years after the steaming was done, this plot grew a heavy normal growth of grain. The picture illustrates how gradually the root fungi were transmitted from the soil of the adjacent untreated ground to the steamed land until the entire soil was again re-infected. Notice the gradual lessening of the strength of the crop from left to right, the plants on the right being thoroughly diseased and characteristic of root-sick or wheat-sick plants.

was considered sufficient seed. Farmers are now often recommending as high as a bushel and a half to two bushels of wheat per acre, regardless of the fact that the grains are often much smaller and hence represent many more plants per acre, and, regardless of the fact that efficient drilling machinery puts the seed into the soil in good growth condition. Some claim that the seed has deteriorated and does not germinate as well as it should. This we find to be true in many cases, and further,

that such failure to germinate is not necessarily due to being heavily injured by moisture, heat and other features, but often to fungus activity inside the seed. This is especially true in Durum wheats.

2. Others complained that their drills skip or miss long areas, thus attempting to account for the spotted nature of the growth when they thought they had used good seed. Our observations indicate that such apparent skipping is more often due to actual dying of the seedlings embryos before breaking thru the ground or immediately after germination, a point which is not commonly noticed.

3. Many complain that plants no longer properly stool. On examination, that is found to be true or to closely represent the fact. Plants are found to start the stools but eventually only a single axis arises and continues to grow. This is usually attributed to lost vigor in the soil. Some have felt sure that such lost vitality is due to growing on the same land too long. This brings them to a desire to continually exchange seed with the hope of getting something that has more vitality.

4. Many noticing the earliest unhealthy growth on large areas of wheat lands have been wont to dig up the grain and investigate for the purpose of locating wire-worms and other insects and have often insisted that the roots seem to be dead as if eaten off. These persons would account for the lost or missing places in the drills by the presence of some imaginary worm or insect which they search to find. If such were the case, it would be necessary to find many thousands of insects or worms to account for the uniform disappearance of the wheat in entire townships or sections.

Some, more observing than others, have insisted that the color of the leaves from the start is hardly normal and that the strength of growth corresponds. A few have called attention to discolored spots, blighted leaves, etc., and have hardly been satisfied by the explanation of other people that these blighted leaves are due to "tip-burn" or "sun-scald." Our investigations find that these observations are correct, not only for scattering plants, but for entire areas, and essentially correct for all of the old wheat areas of the Red River Valley, and the older lands under more or less continual cultivation wherever observed.

5. Others have observed that large areas now called "alkaline" but which once produced very heavy wheat no longer produce the crop and have assumed that the soil has become more alkaline. The wheat becomes black-rooted and dies when but a few leaves high. This, in spite of the fact that the land has been under cultivation for many years and the drainage arranged for is much better than in previous years when wheat



Fig. 29.—Plot Sterilizing by Steam: The plan here shown admits of steaming the ground to a depth of 18 or more inches so that within 4 hours a temperature of 80 degrees centigrade may be reached. The work is done discontinuously over a period of 72 hours, and seems to result in essential sterilization of old wheat soil so that the steamed plots produce a crop which equals and sometimes excels in growth of straw any grain that which is produced by any type of soil fertilization, even tho such small plot is surrounded on all sides by diseased wheat and diseased lands. This encourages us to believe that when lands are properly purified by rotation and tillage and seed is properly purified for large areas, great improvement will be made in cereal cropping.

once grew on such areas. We find that a slight excess of alkalinity plus root fungi is very destructive to wheat, but when such land is purified, the wheat thrives well. (See fig. 36 and 37).

6. All complain of much straw and light grain, yet find when the yield is reasonably high in bushels, the grade is off regardless of whether it is well harvested or not. This does not, as one might suspect, indicate lack of nitrates in soil, but

Table No. X. Effect of Various Artificial Fertilizers and Methods of Soil Purification on Weight of Straw and Grain Produced: These experiments have been run as definite plot trials on beds 20 ft. square worked uniformly by hand for the years 1907-13, inclusive. Each bed has received a known amount of fertilizer applied at the proper time and in a proper manner to make it evenly effective. Each bed has been harvested each year on the day it reached a standard grade of ripeness comparable with other beds, and the product has been cured under canvas and threshed only when thoroughly cured and dry, the straw and grain weights being taken on the day of threshing and cleaning:

The weights given are averages for the period covered. (See Figs. 81, 82, 33, 34 and 35), also Table No. XI.

Plot No.	Treatment	Average weight of straw and grain.		Average weight of Cleaned grain.	
		lbs.	ozs.	lbs.	ozs.
1	Formaldehyde purified six years, Steam last year 1913	41	9	9	0
2	Soil Untreated	39	2	8	9
3	Neutral Bone Flour	41	11	10	4
4	Acid Phosphate	39	6	8	6
5	Muriate of Potash	32	5	7	8
6	Sodium Nitrate	40	1	8	8
7	Kainit	35	8	8	8
8	Tankage	47	11	7	2
9	Potassium Sulphate	30	1	7	3
10	Lime and Potassium Sulphate	38	6	8	6
11	Mixed fertilizers	33	14	7	6
12	Iron Sulphate	31	15	7	7
13	Clover each year with the wheat	37	4	7	6
14	Dried Blood	41	0	8	7
15	Copper Sulphate	33	4	7	1
16	No treatment, coal dust last 2 years.	38	8	7	11
17	Well rotted compost	35	13	5	11
18	Soil Untreated	37	10	8	15
19	Lime, 4 years	38	13	7	14
20	Common salt 5 years	32	10	5	4

It is evident, as indicated above, that fertilizers effect the yield. However, the quality of the grain must always be taken into consideration rather than the weight alone. Some of the fertilizers produce short stiff straw and a small amount of grain of high quality, others, as compost, sodium nitrate and dried blood in the presence of the diseases, produce a large amount of straw and a small amount of poor shrivelled grain.

rather the contrary; for this immature, shrivelled grain is apt to have a comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, "pie-bald," "blighted," "black-pointed," also showing pink, brown and other colorations of the berries even though there has been no moisture at harvest time. These pe-



Fig. 80.—Characteristic wheat plants of same parentage and weight of seed planted on same wheat-sick soil, 40 years in wheat. All plants were of same age, planted four inches apart in the drill; (1) Type plant, practically dead of "tip-burn". Notice the dead roots and blighted leaves; (2) Somewhat stronger, but unable to stool or live as all its roots are essentially dead; (3) Typical plant showing effort to re-root or hold on to the ground. The only living roots are ones which carry the dirt, the new roots sent down after the older lower roots were killed by fungi, resident in the soil; (4) Average plant from the same seed, except the soil was properly purified of parasites. (See Fig. 29.) Such a plant cannot be pulled up by the roots without breaking off the tops. Plants such as (1), (2) and (3) live on the surface and are blighted by the first hot winds or sun, no matter how fertile the soil or how deep plowed.

culiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of the fungi or to changes caused by them.

7. The most common complaint is the formation of yellow leaves on the young plants as soon as they appear followed by what is described as "tip burn" and "sun scald." Upon examination of these soil areas, it is found that this condition corresponds to the areas in which the deterioration of wheat is the greatest at harvest time. Examination of the young plants showing this so-called "sun-scald" and "tip-burning" is always associated with plants which have discolored underground portions, plants which are tobacco colored or creosote colored below the ground line with deficient root systems and poor stooling, tillering, capacity. Indeed such plants are found never to stool regardless of the fertility of the soil. The young buds or stools are blighted early. This shows plainly how difficult it is to properly judge the value of a variety if the grounds on which it is tested should chance to be diseased.

8. There is general complaint that when attempt is made to improve the sick soil by the addition of barnyard manures or by careful working there is great danger that the straw will lodge, grow to a disproportionate height, form keen joints and tumble over even though there is slight weight of grain in the heads. These observations apply to the fertile lands, and do not hold so markedly true on dry land areas, or on very light lands, except in years of spring drouth followed by heavy rains at heading time. Such straw turns "mouldy" very easily when subjected to any dampness in the shock.

9. We find that in such cases the tissues of the too succulent or vegetative straw are early broken down by the ramifying filaments of the invading fungi, and the straw can not stiffen as it matures. Some report that rusted fields no longer show the same characteristics of rust that they did in the early days of new land culture when the straws might be badly rusted, yet grow bright colored heads, chaff and straw. Fields now quite commonly take on an ashy grey or mold color after which the grain never properly fills. This holds true for large areas. On new lands, it is possible to have badly rusted straw in which the bright color of the straw remains, excepting only where the rust spots are but on the wheat-sick areas the straw grows ashy grey, even though few if any rust spots are present. On such straw we find that the grains do not fill because they are cut off from the food supply in the mother plant by the action of the fungi on seed straw and roots.

10. At harvest time, on these wheat-sick lands, it is observed that the stubble takes on this ashy color at once. In

new land areas or upon the land areas in which the wheat does not show the marked deterioration, the stubble remains a bright color for a considerable period after harvest. By such colorations, one can map the areas of wheat-sick soil, even in a stubble field. Different parts of a field often show great variation in yield even though there appears to be no variation in the ground quality. When the grain is cut with a binder, the color of the stubble marks out all these areas. The high yielding grain comes from the bright colored stubble, the low yielding grain from the ashy or dark colored stubble. Properly well stooled stubble showing three or four straws to the stool are usually brighter colored than the plants which show only



Fig. 31.—Note the peculiar irregular growth of wheat on wheat-sick soil. This photo shows part of one of twenty, 20 ft. square plots, which for a number of years have been given equal treatment in every manner, except as to the mode of manuring, fertilizing or purifying. The seed originally used was of like character over all plots. Each year since, each plot has been seeded with wheat raised on the plot and graded to the best one-third before sowing. Compare the growth in this bed with that shown in Fig. 32 and 33, respectively.

one straw to the stool. When these are pulled, a marked difference in the coloration of the underground parts is noticeable. A strength of the root growth corresponding to the stooling may be observed at any time during the season. As such wheat-sick areas and normal areas coalesce, and as stooled and poorly stooled plants often grow side by side, it is not possible that

these differences can rest on a basis of chemical content of the soil.

11. Many have noticed that when they plow up a new piece of prairie land which has lain idle for many years that the area immediately adjacent to the old wheat land is not apt to produce as good wheat as the more distant areas. This is a common observation in flax and wheat cropping and is due to the drifting of the infected dirt.

12. Many have complained that it is impossible to fight quack-grass on wheat lands even though a careful bare summer fallow is practised. Many assert that they have worked the ground over a quack-grass area until there should be no question as to the wheat having a fine opportunity to overcome the quack-grass, yet it never does. Though the quack-grass produces only scattering plants, there is little or no wheat on such areas at harvest time. The writer has many times observed this feature. Usually it is assumed that the heavy rooting quack-grass and its tough humus forbid the growth of wheat. Inoculation experiments prove that the quack-grass bears many of the root diseases of wheat, and thus the wheat can not thrive there.

13. Farmers have complained that they can tell exactly where the manure spreader has been used by the reduced grade of the wheat produced. There is commonly an increase in bushelage but the grade is off and the straw ragged. The writer has visited fields in which it was evident that the young wheat plants, on the areas where the manure spreader had carried the fresh stable manure, were irregular in growth and color, blotched, blighted, and not thriving as well as on the adjacent unmanured areas. Many plants die there by wilt or blighting while young and many others showing evident deficiency in color and strength while some show real increased vigor. Such manured areas are usually characterized by great irregularity of final stooling and heading, and show many blighted parts.

14. It has been proved, by the average results of many Experiment Stations of this country and of the world, and is assumed by practically every capable agriculturist and farmer that heavy wheat seed is more effective in crop production than light weight seed of the same pedigree. This has usually been assumed as due to better food supply at the beginning as furnished by the parent seed. There have been many contrary results difficult to explain. We find that light weight seeds are nearly always internally infected by root diseases which make it impossible for such seeds to compete with plump, comparatively disease free seeds.

15. Farmers complained that screening to large grains gives poor results, and experiments have proved that large,

light weight seeds are deficient in crop production as compared to small seeds of heavy weight character. We find that seeds which have been damp in the shock "bleached and blistered" never can be made to produce crop equal to seed, saved dry from the same field, because wet seeds become internally infected from surrounding diseased heads. Such seeds are also considerably enlarged.

16. The crop is often found to be only surface rooted when there has been good deep tillage and where there is plenty



Fig. 32.—Properly composted manure applied to wheat-sick soil does not usually tend to normal seed production, but rather to make an irregular growth of straw and shrivelled seed. Notice the irregular growth of the heads and the evident weakness of the straw in the lower joints. Such fertilization makes the straw more susceptible to attack, if fungi are present. If the soil is purified by rotation, tillage, or other methods, then the wheat can make use of the compost.

of sub-soil moisture. In this and following bulletins, it will, I think, be made plain that soil infection and seed infection have broken many a hope for a large crop and have vitiated the conclusions drawn from many well-planned schemes for improving the wheat crop. The foregoing symptoms we think are more easily explainable on the assumption of infections or transmissible diseases in the crop, the seed and soil than in the assumption of depleted or exhausted land. Thus while one should use every effort to increase the fertility of the land, he

should be sure that disease infection does not undo all of the careful work of cultivation and fertilization.

Original Research: Formaldehyde Treatment Beneficial in Absence of Smut: During the seasons of 1890-1900, the writer commenced careful studies upon the life history of smuts of wheat, oats, and other cereals. After a number of years, it was determined that smuts not only produce damage in certain stools of wheat, in which the smuts show in the head but often cause much shrivelling of grain in plants other than those which finally produce smut in the heads. It was found that a

Table No. XI. Showing Effect of Fertilizers on Durum Wheat, Kubanka, Pure Line Selection: The data in the table show crushing weights as affected by fertilizers and the occurrence of disease. (See Figs. 31 to 35.)

Variety Plot 21.						
Seed.	Fertilizer.	Occurrence of Black Points Per 100.	Crushing Test of Black Point Grains (Best Seed)	Occurrence of Piebald Grains (per 100)	Crushing Test of Piebald Grains. (Best seeds)	Crushing Test of Normal Grains. (Best seeds)
0	Millet every other year....	44	17300	22	18860	17385
X	None	29	13605	8	12565	15285
1	None	35	11762	5	11465	12920
1½	Compost	37	13555	28	11900	15655
2	Iron Sulphate	27	12885	20	11580	13400
3	Tankage	47	15060	16	13185	18450
4	Kainit	42	16960	30	13520	18470
5	Mixed Fertilizers	37	14795	39	12765	16640
6	Sodium Nitrate	40	16200	17	14565	17405
7	Acid Phosphate	28	18745	27	12100	19105

Black pointed grains are usually clear colored, hard grains of less weight than the normal best grains. Piebald grains are the so called soft, mottled or white belled grains, always being affected by *Fusarium* and various other fungi, while the black pointed grains are almost always internally infected by *Alternaria* and quite commonly by other of the wheat-root diseases.

It is to be noted that different fertilizers do affect the character of the grain and to a certain extent affect the percentage of diseased grains noticeable. No fertilizer, however, has stopped the appearance of either kind in any year. Climate and weather conditions have much to do with the occurrence of the diseases in the interior of the grains. One year one kind of fertilizer produces nearly disease free grain; another year it may be another kind of fertilizer which makes the best and most disease free grain. These conclusions with one selection variety are borne out by the results obtained year after year for eight or nine years on over 100 strains and it is ascertained that by consideration of all of the tables that the most important feature in all cases is variety associated with weather. The percentage of black points rises in hard wheats and tends to disappear in soft wheats, while the reverse is true in the case of the piebald or white belled grains.

large percentage of plants may be attacked by smut and yet only a small number finally show smut in the grain or head. The conclusion was correctly drawn that smutted grain, not only injures the crop in proportion to the amount of smut produced but reduces the yield and grade of the grain thru shrivelling of the seed of many unsmutted heads. It was also observed that the formaldehyde treatment then being developed

by this department gave an increased yield and a better grade of grain. In these smut investigations, it was further observed that the straw on a treated crop of wheat often reached a height five to six inches greater than that of untreated grain. This was very apparent if thoroughly smutted seed was used. It was also apparent if wheat was used in which no smut could be found. These features were very con-



Fig. 83.—Phosphates in any available form, particularly acid phosphate and neutral-bone flour, as shown by beds (3) and (4) of this series have always tended to produce plump wheats on wheat-sick soils. Notice the stiff straw, the more even growth of heads and the comparative value of the crop as illustrated in the photograph. We do not assume that this is because the soils need phosphates; for steamed plots and formaldehyde purified plots as well as ones purified by crop rotation and tillage give equally as good results or better. It is probable that the effect of the extra phosphates acts chiefly through hardening the straw and by hastening the maturity of the seed, thus preventing undue fungus activity in the tissues. (See Fig. 84.)

fusing and led to the conclusion that formaldehyde either had special tonic properties or else largely controlled other seed borne infections unknown.

Light Weight vs. Heavy Weight Seed: During the same period of years, the writer was much interested in the work of demonstrating the value of light weight and heavy weight

seed. Many investigations had quite conclusively shown that heavy weight seed taken from the same bin would show quite an increased yield over light weight seed but such experiments could not of necessity prove that such would be true if the variety tested were a pure bred one. There have also been contradictory results obtained by some investigators.

The writer commenced a series of experiments to test out the growth powers of light weight seed and heavy weight seed from the same pure bred strain and from the same stools and from the same heads. Extensive experiments were conducted in this line, the details of which have not yet been published because at the time I was unable to explain the results. In these experiments generally there was a slight increase of growth and yield shown in favor of heavy weight seed. At times these results would be reversed and no explanations were apparent. The conclusions to which I came were: (1) that a small seed of the same specific weight as a large seed from the same head is essentially as good to breed from as the larger. (2) If the light weight grains are in any manner less plump, off color, slightly shrivelled as compared to the heavy weight grains from the same head, then there is almost uniformly in the product a percentage of size, weight, quality, and yield in favor of the large seed. This fact was often reversed especially if the large seed chanced to be somewhat less perfect as to color quality, or physical texture, yet, there were unexplainable exceptions. Our experiments, as outlined, in this bulletin now make it possible to carry out such an experiment and draw the proper conclusions. While the ground on which we were, at that time, working was very uniform as to chemical content and physical texture, we were deceived in its wheat producing character. We now know that it was not necessarily uniform as to its disease breeding qualities. While we used a large number of pure selection strains to carry on this heavy and light weight seed contest, we, at that time, thought breed, fertility and soil tillage to be the chief factors, and that we had an experiment in which the contest was equal. We were not taking into consideration the possibility of internal infection of seed grains. We know now that those experiments were not on an equal basis with reference to internally borne seed diseases or on an equal basis with reference to soil infection.

Results With Flax: Beginning about the close of this set of experiments, extensive trials were being conducted along the same lines upon the flax crop. From 1890 to 1900, every conceivable line of field trial and laboratory test of growing qualities was undertaken to ascertain why it is that, on the average, one, two or three crops of flax upon new lands appears to leave them in an impoverished condition for the growth of

flax. Experiments were conducted to determine if such land had lost its chemical fertility. It was ascertained definitely that such flax tired soils were not only fertile as shown by chem-



Fig. 34.—Comparative yield of straw and grain from an equal number of seeds, on equal areas of wheat-sick ground: Bundle No. 1 from formaldehyde purified soil; Bundle No. 2 from untreated area, (check plot No. 2); Bundle No. 3, crop from area fertilized by proper use of acid phosphate. (See figs 31, 32, and 35 also Table X).

ical analyses but fertile as shown by the growth of other crops. It was, however, just as definitely determined that ordinary flax could not survive on such "so-called" "exhausted" flax lands. This series of experiments resulted in the discovery of certain fungus parasites which grew on and in the seed of the flax crop and when once introduced to the soil remain there, destructive to further flax cropping.

It was found that the addition of fertilizers, not only did

not have any beneficial effect but often only increased crop destruction.

Further experiments proved that the seed transmitted the troubles to new lands and that it might be transmitted by flax straw, by barnyard manures containing flax straw, by wash waters and blown dirt, etc.

Another set of experiments proved that such soil could be made to produce a good crop of flax if purified and if bright, clean seed were used.

Yet other experiments proved that seed disinfection is necessary to prevent the introduction of the diseases on new land. Other experiments showed that it is difficult to free the land of disease when once present, but that it can essentially be done if proper rotations are followed, proper seed selection and seed treatment conducted.

Finally, by breeding experiments, it was shown that flax strains can be selected and so developed as to disease resistance that a full crop of flax even larger than anything raised on new land, can be grown upon such old flax-sick ground.

These experiments upon flax and flax cropping soils proved conclusively that the characteristic symptoms of deterioration in soil as evidenced by the flax crop did not mean that such soil had deteriorated chemically so that it could not produce flax, or that it contained any lasting toxic products, but ended in complete proof that the flax crop does not, of necessity, cause soil deterioration from a chemical and physical standpoint, either thru depletion or addition of chemical matters. It was found that unsanitary features, conditions of soil and seed infection account for such apparent soil deterioration and consequent flax crop depletion. Other crops than flax evidenced no difficulties in growing there without addition of fertilizers.

These facts, as worked out for the wheat crop with reference to smut, for the flax crop with reference to wilt, and for the potato crop with reference to scab and blight led the writer to plan a series of experiments along the same line in wheat to ascertain the cause of deterioration in the wheat crop. From the beginning numerous mycological and histological preparations and studies were made (1890 to 1900) with the belief that there were destructive fungi generally at work upon the wheat crop other than smut and rust. These laboratory and field studies have resulted in records of destructive work by various types of the imperfect fungi which had, up to that date, been recorded by botanists only as saphrophytes, decay forms. It was ascertained that certain species of *Macrosporium*, *Alternaria*, *Helminthosporium*, *Fusarium* and *Colletotrichum* were all destructive blighters of ovules. It was found during heading time, when the farmers were complaining of the grain not fill-



Fig. 35.—Wheat grown on constant wheat cropped plots, one and four. No. (1), formaldehyde purification bed: No. 4, acid phosphate fertilized bed. The type of wheat produced on these two plots is of comparatively equal weight. The character is different. The phosphate produces somewhat plumper more starchy grain than the grain produced under the formaldehyde purification, where the more normal type of five wheat is raised as to color and texture. Soil purification brought about by steam gives results as to color and weight similar to that obtained under formaldehyde, but softer straw. The seed is heavier and less starchy but about equal in production to that obtained under phosphate manuring.

ing because of damp weather or because of hot winds, etc., that the upper third or half of the head was often empty. The young pistils and stamens, though perfectly formed, were often completely blighted or destroyed. Pure cultures and sections made from these blighted flowering parts of the wheat plant invariably showed the presence of one or more such fungi. Conclusions reached were that under certain weather conditions such organisms are great blighters of flower parts and young ovules.

Effect of Weather, Climate: The author, at that time, believed that the power of such fungi rests essentially in their ability in the presence of heavy dews, slight rains and hot sun to attack "sun-burned" or "sun-scalded" young ovules, and were probably not able to do injury unless the wheat plants were first harmed by weather conditions. It was, however,

Table No. XII. Comparison of the Growth of Purified Seedlings on Disease Infected, Alkali Soils in Contrast with the Growth from Purified Seedlings on the same Soils Purified by Steaming: (Pot Experiments, Crop 1913). (See Figs. 18, 36 and 37)

Soils.	Experiment Number.	Percent of water Soluble Alkali Salts	Seed Treatment.	Steamed soil—Total weight in grams of plants produced.	Unsteamed Soil—Total weight in grams of plant produced.
Kelly (1)	125	0.275	Purified in agar	8.37	1.59
Wilson (2)	17	0.250	Purified in agar	3.27	1.96
Kelly (3)	40	0.740	Purified in agar	2.17	3.40
Wilson (4)	302	0.435	Purified in agar	4.39	1.84
Edgeley (94)	23	0.124	Purified in agar	2.37	3.45
Edgeley (95)	20	0.216	Purified in agar	1.80	.....
Edgeley (97)	33	0.136	Purified in agar	2.14	1.70
Edgeley (98)	300	1.740	Purified in agar	3.16	2.21

The per cent of water soluble alkali in this work was determined by Professor Ince of the Chemical Department. Soils marked "Kelly" came from Kelly Farm, Devils Lake. Soils marked "Wilson" are new land soils from Fallon, Montana. Soils marked "Edgeley" are from wheat and oat soils near town of Edgeley, North Dakota. The seeds used were select seeds of equal weight from individual five heads, one for each pot. Contrast tables show the same work for the untreated seed on untreated soil and untreated seed on treated soil and bear out this same apparent relation of alkalinity to disease as indicated in this table.

apparent in all the histological preparations made that such fungi showed essential characteristic of parasitism. We have since learned that such organisms while, perhaps, largely active as decay forms are strictly parasitic for certain cropping plants; and that the influence of the weather is great in determining crop destruction though not necessary to attack. The blighting of the young ovules or seeds can take place in the absence of good normal wheat weather but is apt to be very destructive when the weather conditions are

just such as would otherwise produce a heavy cereal crop. The grain may be badly injured by them in the ear under the finest types of wheat weather. Botanists, however, had usually recorded such fungi as mere decay forms living in abundance on decayed straw and other dead or dying vegetation.

Disease Garden: A series of experiments was undertaken, a garden was laid out in 1900 with a plan of procuring

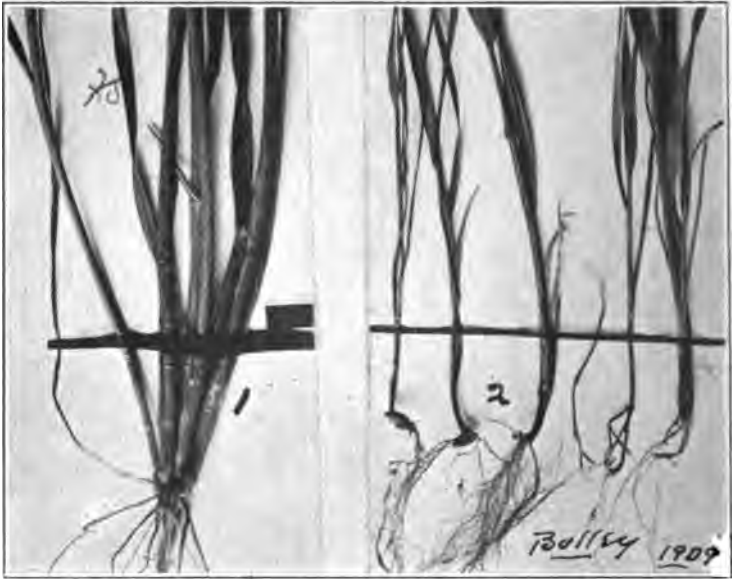


Fig. 36.—It has been assumed by some that deterioration under constant cropping is due to a lack of proper ammonification or freeing of ammonia by micro-organisms. This photograph shows that if ammonia is added to wheat-sick soil in the form of ammonium sulphate when diseases are present on the seed or in the soil, growths may result similar to those plants shown at (2). If, however, such soil is properly purified by steaming, and the seed is properly purified before planting, the addition of the ammonium sulphate gives added growth or strength as shown in (1). *When a valuable fertilizer is present, and the roots are dead by disease, the wheat plants cannot make use of it. If the roots are healthy, they can make use of it.*

disease resistance crops of flax, wheat, oats and other cereals by means of **disease propagation** on soil and on seed for the purpose of **accentuating the disease possibilities** so as to give **better opportunity** for study and opportunity for selection of the sturdy types thru the elimination of the weak ones.

Under this line of work, the rusting problem was first considered in its affect upon the cereals, especially upon wheat.

Methods: While the author did not then know of any generally destructive diseases other than rust and smut, his observations and experiments led to the belief that possibly

other indefinite forms were concerned. Every effort was made in the disease garden to introduce conditions which would bring about the most destruction by disease. The seeds, after being selected to the highest conception of quality or type desired were smutted with the spores of the various kinds of smut. Old wheat stubble and straw presumably containing the germs of any root diseases or blight were plowed into the land. Continuous cropping methods were practised so that any persistent soil diseases might have opportunity to arise and increase in quantity. At planting time all of the beds were evenly prepared. Special methods of planting were practised, planting at different depths on different days, seed treated and untreated, etc. Certain beds were fertilized in special ways, other beds of soil were sterilized in various ways. The latest methods of plant breeding, as conducted by agronomists were carried out on these soils, with closely associated check plots. After the young plants were up, few weeds were allowed. Every effort was made to secure for each kind of disease or disease symptom its choicest condition of environment in soil and atmosphere. For example, the choicest host plants for stem rust (*Puccinia graminis*) also for leaf rust (*Puccinia rubigo-vera*) were intermingled in the various wheat plots. Winter wheat plots were interspersed among spring wheat plots so that this winter wheat might have an opportunity to carry over diseases from season to season, starting them early in the spring upon the spring crops before they otherwise might be attacked. Borders of non-disease-resisting plants were placed around the most resistant sorts. Barberry bushes were planted at intervals between beds for the purpose of carrying the sexual stage of wheat rust. Each evening on those days not suitably foggy or moist, the rust infection plots were evenly struck with a misty spray so as to befog the leaves and foliage with the spores of each disease producing organism. Spores of such diseases as loose smut, stem rust, and leaf rust, were added to the water and sprayed upon the crop at the proper stage of development of the crop. In this garden we planted the best seed that could be obtained of the different strains or varieties of wheat and other cereals thought likely to give light on the subject, together with poorer types of injured grain, as moldy, bleached, blistered, etc., to ascertain the disease reactions under such conditions. Wheat grains of the same variety were selected, as to color, size, weight, plumpness, shrivelled effects, and those which showed special indications of disease, as "black-pointed," "white-bellied," pink colored grains, etc. Each lot was given special bed and special growth conditions.

From 1900 to 1906 chief attention was given to the rust



Fig. 37.—The Effect of Soil Alkalinity plus Wheat-root Infection: In this series of pots, the seeds were from the same head and were of equal weight. The soil for the pots was taken from an over-alkaline area in a wheat field at Devils Lake, Clark Kelley Farm. Under (A), soils were purified by discontinuous auto-claving, steaming under high pressure. Under (b) soils were not purified. Under (A) pot marked "19" represents the growth from purified seedling in the purified soil. Pot marked "16" shows the growth from unpurified seedling on purified soil. Under (b) the left pot shows the growth from purified seedling on unpurified soil. The last pot, marked "1912", represents the growth from an unpurified seedling on unpurified soil. This experiment with others of similar nature demonstrate that many of the so-called alkali spots fail to develop normal wheat not because of over-alkalinity, but because of high alkalinity associated with root diseases. When such soils are purified of root diseases, wheat thrives there. This is an exactly similar finding to that which has been previously worked out for flax by this Department. Wheat can stand high alkalinity of soil, but it cannot do so in the presence of root-blighting fungi. (See table No. XII).

problem to ascertain the results of such conditions upon that disease and upon the crop. Notes were taken from day to day from the time the seeds were planted until harvested. The seeds were always saved, recorded as to characteristics, and again prepared for planting on the following years on the same soil, or on special check beds.

These experiments with numerous widely distributed field observations, resulted in the following conclusions: (1) **There are other more destructive diseases of wheat and of allied cereals than either stinking smut or black rust of wheat;** (2) A number of all of these diseases may act upon individual plants, or upon the crop separately or together; (3) Weather and soil conditions which tend to favor one of these fungus troubles are apt to be favorable to the others; (4) When all are acting together the sturdiest wheat selections cannot be expected to mature normal seed, though it now seems to be proved that certain selections made under the conditions of survival indicated above are much sturdier than ordinary. During these years of experiments and observations, many strange anomalies in cropping have been recorded, for example: (1) Wheat crops containing much smut with the rest of the grain essentially of normal plumpness; (2) Associated strains on same lands, with but a slight amount of smut in the crop the rest of the grain thoroughly shrivelled; (3) Crops of very rusted wheat straw, in which no plump grain could be obtained; (4) Crops of equally rusted wheat straw so pronouncedly rusted that there were hardly any straw-surfaces free from pustules and yet the grain was plump; (5) Crops with essentially smut and rust free straw, yet no plump grain.

There is also much evidence that certain pieces of soil tend always to give similar types of shrivelled or "deteriorated" grain, showing peculiar markings, colorations and types of shrivelling. These soil and seed troubles were observed to be directly associated with approximately constant wheat cropping, or with the use of seed from such regions. The problem was then attacked in various ways with the view of ascertaining causes.

Outline of Special Investigations and Conclusions: The following outline, in part, indicates the field of investigation on which we have based the conclusions as to the cause of crop deterioration and apparent soil deterioration.

1. **Normal and Abnormal Features of Crop and Seeds:** We have made a survey of normal and abnormal peculiarities of the various varieties of wheat and other allied crops, especially as applied to the seeds, and the growing plants. Special studies have been made in the laboratory, seed houses and on farm crops, under special conditions. The field examinations

have extended into the wheat regions of other states, including studies upon winter wheat, barley, etc. A very close study of the wheat fields of North Dakota has been conducted upon the various types of soil. This survey brought out the facts: (a) That there are a number of diseases of wheat other than the commonly known ones which show such specific characteristics that any observing person can detect them on young growing plants and maturing crops, on the stubble, on the roots, or on the seed in the bin; (b) That the crop is often attacked not by one fungus alone but by several under such conditions that it may be difficult to specify that a given trouble is produced by one particular fungus, for example, internally in the same seed there may be present two or three species.

Black pointed grains may be caused by one or more specific fungi, the species of which can only be determined by histological and cultural methods. Seedling wheat plants when one to four or five blades high may show certain peculiar characteristics of the roots. On wheat-sick areas, throughout the Northwest, the under-ground portions of such young plants almost uniformly carry a creosote or tobacco colored darkening of the stem portions and sheathing portions of the plants while normal wheat plants from undiseased grains occurring on clean virgin land or on



Fig. 38.—Blowing disease bearing dust and dirt onto the other fellow's farm and on to the soils of the native prairie heretofore free from such diseases as described in this bulletin.

purified soil are invariably white, yellowish white or greenish white in their parts below ground. Some of the plants often show these dark or creosote colored portions on the first and second joints above ground at about the time when the grains begin to head out. At least four parasites have been removed and tested which are able to produce this peculiar creosote col-

oration. The intensity of the color effects of these vary. In some cases the action or results of one parasite may be so intense as to mask the color of others fully as destructive. Fungi, known under the generic names: *Helminthosporium*, *Fusarium*, *Colletotrichum*, *Alternaria*, *Macrosporium*, each apparently have capabilities of producing the creosote coloration though it is perhaps most pronounced under the action of the first two

Table No. XIII. The Drifting of Parasitic Fungi by Winter Winds from Field to Field: Studies have been made by centrifuge examination of snow-drifts. After melting a large volume of snow and thoroughly shaking the resultant water, the same was filtered thru ordinary filter paper. The residue after drying was examined in 10 gram lots, centrifuged in 10 cc of distilled water. Different drops of the residue found in the centrifuge were examined by microscope, and pure cultures were made from other drops from the same solution. Fifteen of such snow drifts were examined in the spring of 1913. Only drifts which were a long distance from cultivated fields were examined. The snow used was taken from the College campus from a close-clipped blue-grass lawn protected by hedges and other shrubbery. The following are the results from two of the fifteen drifts:

Microscopic Examination				Plate Cultures.
Drop 1.	Drop 2.	Drop 3.	Drop 4.	Growth on Agar Cultures.
Drift No. 1 Resting spores of wheat rust, Spores of <i>Alternaria</i> . Various Fungal Filaments, Bacteria.	Resting spores of wheat rust. Spores of <i>Alternaria</i> . Various Fungal Filaments, Bacteria.	Spores of wheat smut. Broken fungal Filaments.	Broken parts of various Fungi.	Bacteria, <i>Alternaria</i> and various molds.
No. 3 Broken Fungal Filaments, Spores of <i>Mucor</i> Sp.	Broken Fungal Filaments, Spores of <i>Fusarium</i> .	Various unknown, undetermined Fungal hyphae.	Fungal Filaments	<i>Fusarium</i> Sp.

Numerous types of undetermined fungal filaments were present in the fifteen different drifts examined. We list the following definite types of spores: Spores of wheat rust, *Alternaria*, *Mucor*, *Aspergillus*, various types of smut spores, *Fusarium* and many types of secondary spores including those of the family of Erysipheae, and bacteria. These results of snow drift examination are directly comparable to previous work done upon the drifting of weed seeds by winter winds. (See Bulletin 17 N. D. Experiment Station, 1895, where it is shown that the seeds of practically all native plants and weeds drift by winter winds and accumulate in snow drifts upon lands other than those upon which they are grown. As the infectious diseases of the grain crops produce countless numbers of spores upon the stubble, it is easy to understand that when a crop becomes general such diseases will drift from field to field and from farm to farm). (See Figures 38 and 39.)

genera named. The wheat lands in which the bulk of the plants show this coloration, when the plants are young, may be counted on to produce shrivelled seed under ordinary weather conditions. If rust conditions also are present the crop may be looked upon as certain to be very badly reduced in yield and quality of grain. In case the plants show a marked tendency to die out when young as if the roots had been eaten off by insects, such plants usually show either a cream colored or a greyish colored mouldy appearance of the plants and roots at or below the ground line. The chief cause of the dying in

such cases, is occasioned by fungi of the genera *Fusarium* and *Colletotrichum*. *Fusarium* often produces peculiar pinkish colorations of the grain and root parts. The fungus, known as *Colletotrichum* appears to be much more nearly a pure para-



Fig. 39.—Picture showing wind action and the dirt bearing nature of snow drifts. Such snow is laden with dirt and dust which has been blown from plowed fields or from stubble fields. Our experiments show that it may also be full of weed seeds and the spores of wheat and flax disease producing fungi, even though the snow examined lies on the native prairie a long distance from any cultivated land. (See Bulletin No. 17 N. D. Exp. Sta., also Table No. XIII.)

site in its mode of acting upon the plant. It is difficult to certainly detect this fungus on the seed and on the roots except by pure culture methods, but is readily recognizable by means of its definite pin-point-like pustules and peculiar hair-like structures which break out upon the stems and leaves and sheaths of nearly mature plants. Each of the various types of injured grains as pink-colored, black-pointed, white bellied, etc., breed true, reproduce themselves. Certain conditions of soil, weather and variety, however, seem to largely affect the development of these features.

2. Histology: Histological studies have been conducted upon normal and abnormal plants, seeds, seedlings, roots, stems, leaves, heads, flower parts, etc., to determine the mycological flora of the wheat plants externally and internally. The chief method in this case has been to imbed, section and carefully study various parts of normal and abnormal plants from the seeds to the mature plants. From these studies we have, from year to year learned: (1) that the fungi which we are now listing as effective in causing crop deterioration and wheat-sick land are essentially cosmopolitan in distribution, and that they are often closely associated in attack, even upon the individual plant; (2) that each of them may be conveyed either by the seed or by the straw parts; (3) that the mode of attack is probably for each of them most direct and most commonly from a previously infected seed, but that the land may become so filled with old straw parts and decaying humus that no healthy

wheat can root there without becoming attacked so that the roots are badly destroyed. **The wheat only hangs on to the ground in such spots because of its ability to re-root and send down new root parts,** it being unlike flax in this respect, flax only having one root to lose dies away leaving a bare spot while wheat clings to the ground and is finally able to send up one or two straws where otherwise it might have stooled freely were it not for the root destruction. Under such conditions, farmers and agriculturists have often blamed tillage methods and weather.

Infection may also take place from the outside by wind blown spores. It is also probable that the most rapid ascent thru the straw from the ground upward to the head is by means of the growth or development of such fungi in the sheaths and sheathing leaves, though this is not necessary as our pure culture experiments show that anyone of these parasites may be obtained from the interior of nodes and internodes of what would to the ordinary eye appear to be normal wheat straw.

3. **Special Plantings:** Special plantings of normal seeds have been made in contrast with seeds of peculiar characteristics as to weight, color, disease markings, etc., contrasting with checks of normal type of seed from the same variety and with apparently normal seeds from the same plant. Such plantings have been made in sand cultures, water cultures, virgin soil, wheat-sick soil sterilized by steam and by chemicals of various types. There have been plantings in pure agar culture medias. These experiments have given us opportunity to determine in a definite way the characteristic plant growth which might be expected from a given type of seed. These plantings have enabled us to appreciate how difficult it is to procure really normal wheat seed and normal seeds of other cereals. Many seeds which would be spoken of as normal by the average judge of wheat are found to be internally diseased or at least so infected thru their seed coats that it is impossible for them to produce a normal plant even though properly disinfected by the ordinary methods of seed disinfection. The ordinary smut treatments on ordinary types of seed give benefit by destroying spores of the wheat root fungi on the exterior, but are usually insufficient to kill the fungi under the bran layers. The very great benefits, however, which are derived from the common methods of treating oats and barley for smut are we believe largely due to purifying the shucks or enclosing chaff scales and bran layers. The chaff scales of oats and barley being often thoroughly infected with root disease producing fungi are very destructive to the seedling plants unless disinfected.

These special plantings of individual seeds and selected

seeds from pure varieties and pure strains teach that in the future fight against unsanitary soil conditions in wheat cropping, farmers have a problem of no small difficulty because of the real difficulty of procuring wheat and other cereals free from internal infection. These experiments make it more easy to understand the conflicting results which have been obtained



Fig. 40.—All native prairie lands new to the plow are not now free from the root diseases described in this bulletin. This photograph shows one sector of a large fairy ring found on the unplowed virgin sod lands of the Yellowstone Valley, near Sidney, Mont. Notice where the mushroom (puff-balls) grow, that most kinds of the native grasses are dead or nearly so. In western portions of North Dakota and Eastern Montana, when such a ring is plowed across, it does not usually produce flax at all. Sometimes it practically fails to produce either barley or wheat. In this particular ring, the tall native grasses are chiefly western wheat (*Agropyron*), and spear grass (*Stipa*). These were usually cankered off by a species of *Colletotrichum*. All native wild flax plants, *Linum sulcatum* and *Linum perenne*, were cankered off or dead on this ring. This holds true in practically all such fairy rings where native flax grows on surrounding lands. These fairy rings are found in many sizes. Different types of mushrooms grow at different seasons. Most such fairy rings probably have origin in the droppings of cattle or horses, pasturing in circles while the snow is on the ground and in the early spring following. The spores of the mushroom and puff-balls, and probably also the resting spores of flax fungi and those which destroy the wheat grasses pass thru the alimentary tract of herbivora benefited in germination and are thus concentrated on such areas and continue to develop there. (See Figs. 31, 41 and 42.)

by different experimenters when working with wheat under supposed accurate conditions of contrast, as, for example, variety tests, crop rotation trials, fertilizer experiments, water cultures, sand cultures, respiration experiments, paraffin basket tests, etc. Sometimes there have been internally infected seeds

sometimes disease infected soils, sometimes infected manures, etc., sometimes not. These infection factors being variable as to presence and always very destructive when present largely vitiate general conclusions from such experiments, especially in case of trials, contrasting individual plants or small plots. It is also now easy to understand why one person may succeed in getting a very much enlarged crop thru certain kinds of cropping and cultivation while another who has more badly diseased seed or infected soil fails to reap the benefits from even a better rotation and better cultivation conditions.

4. Fertilizers and Disinfectants: Experiments have been conducted with artificial fertilizers and soil disinfectants applied to plots of wheat disease infected land, using seed of known origin and of like strain. These experiments show that wheat-sick soil can be disinfected in such manner that a very much greater growth of straw and grain may be realized and associated with a great improvement in quality. The improvement, as shown by some fertilizer trials is often very marked. It has been clearly proved in our experiments that certain additions of fertilizers produce marked results in the quality of seed. We find that these improved conditions as to seed are consonant with a lessened apparent virility of attack in the various fungi upon the straw and upon the seed. Under the conditions in which we have worked in the field, we have never been able to entirely eliminate the presence of the diseases thru the use of chemicals or fertilizers. Some one or other or several of the diseases may be found upon essentially every straw of all the plots, but in comparative amount and effect, they are found very greatly reduced under certain treatments and crop improvement follows. See notes on weight quality, crushing quality, color quality, milling tests, etc., as stated elsewhere in this bulletin.

5. Soil Sterilization or Purification and Seed Disinfection: Experiments in soil sterilization and seed disinfection have been conducted, as follows: (a) Disinfection to eliminate internal infection of seeds for pure cultures in agar and for trial in individual sterilized pots; (b) Purification or disinfection of pure bred strains of seed for contrast with similar pure selections not so purified for trial in field plots; (c) Purification of large areas of ground in the field by means of steam in which the ground was heated for a depth of from fourteen to eighteen inches, etc. The results of these experiments indicate that ordinary fungi and bacteria so far as the individual wheat plant is concerned have little influence on its growth.

Sterilization of soil always gives improved first growth even though the seed is of poor quality and much diseased. If the seed is much diseased, sterilization often does not show con-

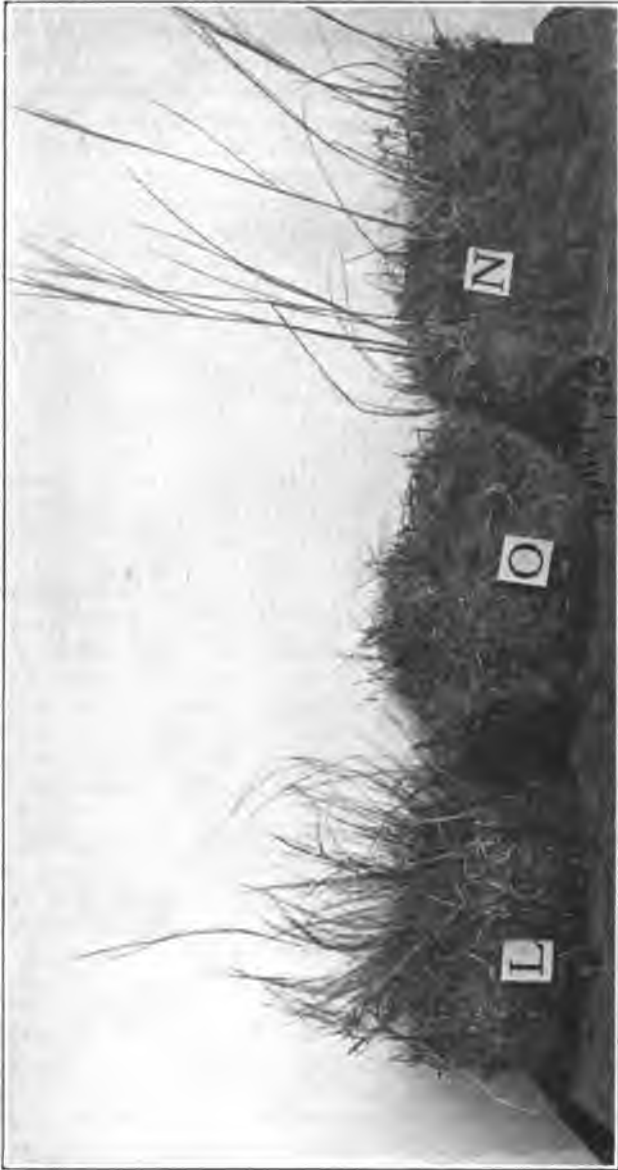


Fig. 41.—Native sods taken from adjoining areas of native prairie near Fairview, Montana. Sod "O" came from the center of a fairy ring where only the Buffalo Grasses, *Bouteloua* and *Buchloe* remain active; sod marked "L" grew on the outer margin of the ring and consists chiefly of the wheat grass (*Agropyron oodendatale*); sod "N" grew in scattering clumps on the margin of the ring (*Stipa spartea*). This grass was mostly broken over or cankered off as shown in the picture. There were also scattering dead plants of the small yellow flower, native flax (*Linum sulcatum*), killed by *Colletotrichum* *flaxi*. No flax survived in the ring or rim proper.

tinued improved growth, but may result in a quicker destruction of the plants.

When soil sterilization is essentially perfect and the seed proves to be internally disease free, the growth of the young wheat plants results in proper stooling, white portions underground, pure white roots, and a heavy growth on lands which have long since been supposed to be "cropped out." These experiments, associated with inoculation experiments, prove conclusively that such increased growths are not due merely to slight chemical change of the ground, such as increased solubility of plant foods; for the simple introduction of a few viable spores of one or other or several wheat root destroying fungi immediately throws the purified soil back into its old condition of inability to produce anything but "tip burned," "sun scalded," creosote colored plants with stubbed, discolored roots. A similar destructive result may be brought about by the application to such purified soils of powdered

Table No. XIV. Effect of Composting Fresh Manures upon Root and Stem Parasites of Wheat and Flax: In the winter of 1903 fresh barnyard manure was hauled direct from the stable and piled in a compact pile until about three feet high, one rod long and ten feet wide. Onto this mass of fresh manure were then laid bundles of flax straw thoroughly infected with the flax wilt and flax canker fungi. These bundles were attached to fine brass wire so that they could be recovered at will. Three feet more of fresh manure was then added and compacted upon them in the form of small but proper compost heaps. After nine months, careful microscopic and pure cultural examinations were made of the flax straw with the result that no *Fusarium* *luni* or *Colletotrichum* *luni*, or other flax parasite were found upon or in the decomposed flax straw.

In March, 1913, three carefully prepared compost heaps 20 ft. by 12 ft. by 4 ft. deep were prepared by hauling fresh barnyard manure direct from horse and cow stables made from the miscellaneous cereal bedding, mostly wheat. Each day the pile was thoroughly tramped and compacted to imitate the proper construction of an ordinary compost heap. Into the middle of these wires were introduced carrying bundles of straw to test. In Compost Pile No. 1 small bundles of flax straw from flax-sick areas were attached to galvanized wires so that they could be recovered. In Compost Heap 2, wheat stubble from wheat-sick areas in small bundles were likewise attached and then more fresh manure was compacted upon the piles so that the bundles finally rested in the interior middle line of the heaps. In December of 1913 the first bundles were removed from the compost heaps and examinations made for the effect of decomposition upon the root and seed destroying organisms. The straws in the bundles were found to be as yet fairly well preserved in texture, but indicated decomposition. Eleven straws from the flax bundles were carefully tested microscopically and by pure culture methods, with the following results: One growth of *Alternaria*, one of *Fusarium*, one of *Aspergillus* and common decay forms of bacteria in all.

From the compost heap in which the wheat bundles were stored, 12 separate culture tests were made and only two of them produced fungi of filamentous form, one unknown organism and one mucor,—all others gave only bacteria.

Test composting in such small compost heaps is of course not comparable in its effects to the work which is done in large farm compost heaps as shown in Figure 42, but the trials are sufficient to indicate that proper composting is very destructive to all filamentous fungi. As the ordinary compost heap remains three years before it is hauled out our tests from those heaps have always shown them to be essentially free from disease producing fungi or weed seeds of any sort.

roots of wheat plants from wheat-sick soil. The results from these experiments are so conclusive that when properly conducted the person who has carried out the experiments can have no doubt that he has observed the workings of specific

diseases, the chief factors in so-called crop deterioration and soil deterioration of the wheat lands of the Northwest. He is also at once in position to better understand the merits of the "toxine" theories of crop deterioration; and the insufficiency of the reasons offered by those who would explain the deficiencies shown in the wheat crops grown upon so-called wheat exhausted lands by merely referring to lost fertility, poor tillage methods, etc.

6. Fungus and Bacterial Flora of Wheat-Sick Soils: Studies have been made in pots and plots upon the fungus and bacterial flora of wheat-sick soils as influenced by special methods of fertilizing. The crop has also been studied as to the influence of fertilizers and chemicals upon the growth of fungi in the straw and grain. Certain methods of fertilizing and purifying such soils really influence the growth of the fungi in the soil yet we have found no soil condition in which wheat can thrive in which the root fungi may not also persist in sufficient quantities to injure the crop. It is very clear that under certain conditions of soil fertilizing in the presence of



Fig. 42.—The common method of handling fresh manures direct from the stables, showing the manner of driving direct over the pile with a dump wagon so as to keep it thoroughly compacted to prevent firefang. Three years of such composting gives valuable compost essentially weed seed and disease free. The outsides of such piles should be removed before hauling to the field.

disease, the destruction to the crop may be very greatly increased or considerably minimized. For example, the addition of phosphates to a wheat-sick soil already containing sufficient phosphates to produce a crop may in the presence of root diseases greatly increase the quality of grain produced. From our experiments, it is evident that the benefits arising from the added phosphates is not due to the fact that the phosphates particularly act like a disinfectant or killer of fungi, but that it has a tendency to harden the straw, making it difficult for the fungi to invade from

the roots upward so as to reach and injure the quality of the grain or sufficiently to cause a cutting off of the supply of moisture and food from below. Ordinary potash, lime and other alkalies were found to be detrimental on many of our plots not as we interpret it because these lands could not stand the addition of further potash, but because, in the presence of certain of the wheat root destroying fungi, which appear to be lovers of an alkaline condition of the soil, wheat is not able to compete with the increased growth of fungi under such heightened cellulose destroying conditions. Again, in the case of the addition of nitrogen fertilizers, if the soil were sterile or free from the fungi it could stand a considerable application as of nitrates or barnyard manures, dried blood, etc., but in the presence of the root destroying fungi such fertilizers induce a soft vegetative growth which the parasitic fungi readily ramify and are able to destroy. Under such vegetative conditions the cellular structure soon becomes disorganized, and the stems either break over or fail to properly function in their work of filling, maturing the grains.

7. Fungus Flora of the Straw and Seed: Studies have been made of the fungus flora or content of wheat plants as grown upon wheat-sick soils, on special fertilized areas, on sterilized plots, and on new soil areas. The purpose has been to procure pure cultures of the fungi which live naturally upon and in the wheat roots, straw, leaves, chaff heads, grains, etc. This pure culture work has thrown light on the subject of cereal-sick soils. It clearly indicates the difficulties involved in any future attempt which may be made to improve cropping conditions upon old wheat-sick areas and in regions where the wheat crop is essentially a general one. The disease producing fungi are seldom absent from any single piece of land. It is seldom any piece of growing wheat straw is free from one or other of such fungi. One seldom finds the interior of a wheat plant which is growing upon wheat-sick soil, or which has been originated from wheat-sick seed that is free from one, two or more of the root destroying fungi. Very often two or three of the fungi are present on the interior of the same seed, the same root, the same node or internode of the straw. Some of them have greater preference for one part of the plant than another with the result that a plant is very apt to furnish cultures of every one of the fungi. **This is especially true if the soil is quite fertile and there is anything like an excess of the nitrogenous over the mineral food elements.** In such pure culture work we have definitely separated species of the following genera which are proved capable of causing the death of young wheat plants or of reducing and shrivelling the grain when applied to the maturing heads. They are *Alternaria*,

Macrosporium, Helminthosporium, Acrothecium, Colletotrichum, Fusarium and Cephalothecium. Each of these can be obtained from the seed coats and interior of the grains from this region and from wheat samples from almost any wheat growing region in the world.

8. Crop Production: Comparative Crop Production on various specifically prepared plots arranged to contrast the quality of grain and straw produced, as above indicated, show that the apparent deterioration of the soil and the evident deterioration of the wheat under constant cropping to wheat are due to the unsanitary condition of the soil and seed because of the direct action of parasitic fungi or semi-parasitic fungi. If correct, such experiments as we have outlined above should give results showing a reasonable relation between the presence or absence of the fungi and the amount and quality of grain, type of straw produced, etc. To determine this each year, the crop weights have been carefully taken and the harvesting dates for comparable plots have been kept so that the samples could be properly compared. Plots have been harvested in such manner



Fig. 43.—Sugar beets are not a good rotation crop for potatoes. Beets carry the disease known as potato scab.

that they were not exposed to the action of moisture, being shocked under canvas or at once stored. We are thus able to judge the quality of grain produced as to color relations, weight relations and milling qualities without having to enter into the question of the influence of weather injury after maturity. Regular weight tests have been made of straw and grain as

soon as thoroughly dry, nit for threshing. To get these tests the straw of the plots compared have been handled exactly the same, pulled by the roots and cleaned off or else cut close to the ground. The threshing has been done in such manner that all of the seeds, no matter how shrivelled enter into the first weight tests of the seed and the total weight of grain is taken. The weight per bushel is recorded in all cases of sufficient sized plots. After standard methods of wind grading, the grain of comparable plots is given a second weight test on the bushel basis and is then judged as to color qualities, milling value, etc., by inspection. Weight tests have also been taken during other periods of growth than the maturity period. These weights necessarily being made upon straw from given areas, air dried. These weight tests show variation from year to year and make it very clear that climatic influences as to rain fall, drought, rust invasion, etc., have a marked bearing upon the conclusions that should be drawn but we have tried to watch the growth of our crops so closely from day to day that we are able to note the influence of these conditions of environment. Furthermore, these are apt to be general factors which apply equally to all of the beds. Our plots are laid out upon soil of very equal chemical fertility and upon areas of land of very similar physical and drainage conditions. Many factors which might be of great importance on certain land areas, with us are minimized because of the almost actual uniformity. From these experiments it is evident that the addition of certain fertilizers to wheat-sick soil have a direct bearing upon the type of crop which one year with another one may expect. Under differing weather conditions, the results vary. It is therefore evident that in fertility tests the average for a number of years will give more reliable conclusions than the results for one or two years. Yet, to understand the influence of the weather or environment upon the fungus activities with relation to the influence of the fertilizers upon the growth of the crop, it is necessary to consider the condition of each year separately by direct study of the individual products.

The weight tests show that usually the deterioration of the grain can be attributed directly to the comparative virility of fungus activity. In some cases this increased activity may be referred to the seed used, and in other cases to the infected condition of the soil or to the direct influence of both diseased seed and diseased soil. Whether we eliminate the general cropping factors, such as intense drought and excessive rain or varying fertility or take these into account, one can, from the grain weights and grain quality as to color, texture and markings, essentially predict the comparative prevalence of the root diseases. This is especially true when one takes into

question the diagnostic features of disease as indicated in color in normally cured grain. For example, the presence or absence of black points, pink grains, the presence or absence of white bellies, the presence or absence of scaly, scurfy grains, or the apparent intensity of "bleaching" and "blistering."

9. **Crushing Tests:** Crushing tests have been conducted upon typical average normal grains selected from each plot under test. These tests have been done at the same period each year upon grains from the different plots when they are under similar conditions with regard to date of harvest,



Fig. 44.—These figures illustrate that thru proper breeding work and standardization of seed, farmers may yet hope to overcome such diseases as are described in this bulletin. These two photographs of flax were taken by Mr. W. A. Peck of the North Dakota Better Farming Association in August, 1913, on the farm of Mr. M. Aakrann of Norwich, N. D. They show well the comparative crop producing powers of the wilt resistant flax known as *N. D. R. 52*. (1) Common non-wilt resistant flax, yield $2\frac{1}{2}$ bushels per acre; (2) *N. D. R. 52*, wilt resistant flax, yield 12 bushels per acre of cleaned seed. (See Bulletin 55 N. D. Exp. Station.)

storage, etc., with the thought that such crushing tests ought to show the influence of comparative presence or absence of disease, the influence of fertilizers and of soil and seed purification. Our conclusions are that the disease factors and the fer-

tilizers do influence the texture of the grains, that the extent of such influence upon grains depends very markedly upon the atmospheric and soil moisture conditions under which the crop is produced.

10. Milling Tests: Milling tests are being conducted on certain products from the larger areas to ascertain how the seed from different plots compares in flour producing quality with reference to the varying amount of disease occurrence, effect of fertilizers, etc. As might be expected, this is rather a test with regard to the value of certain methods of handling the land in connection with the presence of the root diseases.

11. Variety and Pure Selection Tests with Check Control: There have been conducted upon thoroughly wheat-sick

Table No. XV. Crop Rotation of Biologically Non-related Crops: Each crop in a rotation should be biologically or botanically non-related,—at least to such extent that individual crops in rotation do not support each other's diseases. The following table is given as a tentative illustration of this point.

Year	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
1st	Flax	Wheat	Hay	Pasture	Corn
2nd	Wheat	Hay	Pasture	Corn	Flax
3rd	Hay	Pasture	Corn	Flax	Wheat
4th	Pasture	Corn	Flax	Wheat	Hay
5th	Corn	Flax	Wheat	Hay	Pasture

When the plot is under cultivated crop, it is the opinion of the writer that practically any cultivated crop may be used other than corn, or several of them may be used to occupy the area, as for example: corn, potatoes, mangels or beans, peas in rows, etc.

In the portion marked "hay", while alfalfa or clover or timothy and clover mixtures are perhaps preferable, the writer believes any pasture grass may be used excepting possibly only the wheat grasses (*Agropyrons*). If fresh manure made of wheat straw is used, it should be spread on the wheat stubble. If fresh manure made from flax straw is used, it should be spread on the flax stubble or on the haylands after the hay is cut.

soil extensive variety trials and pure pedigreed selection trials under contrast to ascertain the relationship of the root diseases to the type or variety of wheat under consideration, possibility of improvement by selection and by elimination, etc. As might be suspected the different varieties and different strains show much variation in crop producing quality but, as a whole, the general varieties of wheat behave in a comparatively similar manner. The disease factors and the fertilizers do influence the texture of the grains but the extent of such influence upon grains depends very markedly upon the atmospheric and soil moisture conditions under which the crop is produced. Be it for bed, a particular fertilizer applied to a particular piece of land has essentially the same general influence upon the quality of crop produced with reference to these diseases regardless of variety or strain. The differences noticeable refer to the intensities of disease action and are always noticeable

in grain quality. While it is evident in considering such questions that the variety and strain must be kept in mind it may yet be asserted that varietal differences are not as great as might be hoped. All beds to be contrasted have been sown with the same sort of pure bred wheat. When such beds are sown with several varieties of wheat the results are found to correspond on a comparative scale and all taken together strengthen the conclusions: (a) that so far as the yield and quality are concerned the question of variety is a matter of great importance; (b) that the diseases act apparently with greater or less vigor upon all of the varieties or strains of wheat; (c) there is much reason to hope for wheat improvement with regard to resistance to such root troubles thru seed selection on the survival of the fittest plan whereby the selections



Fig. 45.—If such a shock of wheat gets wet before being threshed, a small amount of wheat-root infecting moulds spread rapidly thru the dampened heads. At least enough seed for your own use should be cured under canvas caps and threshed dry to escape the activities of the seed deteriorating fungi which attack wheat. The slogan must be "Hard Dry Seed."

are made after greatest possible exposure of the grain under trial to the action of the root and seed diseases. Our selections of wheat, made on such special disease propagation garden show many of the resistant features evidenced by the strains of resistant flax which were obtained in this manner. I believe the wheat improvement problem is of the same nature only more difficult because of the greater number of diseases.

12. Inoculation Experiments with Straw, Manures, etc.:

(1) We have conducted numerous plot and pot experiments in which we have used stubble and chopped straw from wheat-sick areas; (2) Inoculation in pots with evident disease bearing seed; (3) Inoculation into pots and plots using soil from wheat-sick areas; (4) Pots and plots inoc-

ulated with manures, the bedding of which was made from straw from diseased areas, etc. Each such inoculation experiment has been carefully checked by control pots or plots. Such trials, after a number of years, have given conclusive evidence that root diseases and seed diseases of the types heretofore described can be conveyed in such ways exactly as in the case of flax wilt in the flax crop, potato scab in potato culture, etc.

13. Inoculation With Pure Cultures: Inoculation experiments have been conducted with pure cultures taken from the interior of wheat straw, from the interior of apparently normal wheat grains, from lesions found upon seeds and seedlings, growing straws, flower parts, roots, nodes, ovules, etc. These experiments show clearly that certain species or strains of *Fusarium*, *Helminthosporium*, *Alternaria*, *Macrosporium*, *Colletotrichum* and *Cephalothecium* are directly capable of destroying or attacking growing plants of wheat, oats, barley, brome-grass and quack-grass. Certain cross-inoculations have been made between the different cereals and some native grasses in sufficient manner to convince that some of these diseases can be transferred from one type of crop to another as in the case of barley to wheat, or quack-grass to wheat, but that in most cases they are comparatively distinct each on its own host. In the case of barley and wheat, a long line of trials on separate years has given evidence sufficient to allow the following conclusions to be made: (a) Barley and wheat are not good rotation crops for each other. Most of their root diseases appear to be interchangeable. In this connection, it is interesting to note that Aaronsohns studies, previously mentioned, point quite conclusively to the probable fact that these two crops have a closely related ancestry and environmental origin.

This cross inoculation has a very important bearing in cropping methods and demands very exacting and extensive experiments to avoid error of conclusion. Such experiments as have to date been conducted will be detailed in another bulletin.

Disease Inoculation and Seed Selection: To carry out our idea of being able to select the most resistant plants from wheat crops which have been subjected to all possible diseases to eliminate the weak, we have for a number of years followed the plan of field inoculation in a large way thru continuous cropping, use of host plants for wheat parasites, spores sprayed upon crop, etc. The same soil is used year after year for such investigations so as to give opportunity to accumulate persistent soil troubles in the way of fungus, parasites, bacteria, etc. The stubble is plowed under and in some cases old straw and strawy manures have been added for the purpose of car-

rying to the soil any straw-borne disease. In other cases, the seed has been thoroughly infected by smuts and other known fungi and in some cases the most disease bearing seed has been selected for planting purposes in contrast with the best available from the same pure bred sample. We have, from time to time, as soon as the crop was growing, sprayed the crop with rust spores collected from various sources so as to insure the attack of the crop. The crop has also been sprayed with moisture at the proper time to allow the spores to germinate. This work naturally led to the use of other fungi, and we find that heading wheat sprayed with the kinds of fungi heretofore listed is at once badly attacked in the flowering parts which may be wholly destroyed. This set of experiments is now being conducted on a more accurate pure culture basis and we will finally be able to report more accurately in detail. By scraping the various types of diseases from the straw and using them in quantity our field spraying experiments for a number of yearly trials resulted in partial or complete destruction of the young flower parts and filling grain; and conclusively show that a crop of wheat of the ordinary type, such as Blue Stem 169, Scotch Fife 163, and most of the Durums can be essentially destroyed in their seed producing power. These experiments point to the possibility of great damage to a growing crop by these diseases thru wind-blown spores from other badly diseased crops and emphasize the importance of having the crop of a given neighborhood grown upon well tilled, properly rotated lands. It is also very important to have the wheat crop of a particular region rather uniform in its maturing period for the reason that evil effects are sure to follow the exposure of immature crops of wheat to windblown spores from the earlier maturing fields.

These spraying experiments also emphasize the desirability of uniform neighborhood or regional crop rotation, and explain, in part, the natural success which comes to a community which practices the more intensive types of farming which results in diversity of crops and less contiguity of like crops.

15. The Influence of Alkalies Upon the Development of Disease: Studies upon the crop as grown on alkaline areas have convinced us that the chief damage occasioned by ordinary alkaline lands is largely heightened or increased by the presence of the root disease of cereal crops. In both flax and wheat a number of definite experiments show that the addition of alkalines to already alkaline areas results in a very much heightened condition of the development of the diseases. In the case of wilt resistant flax, flax which is thoroughly resistant to wilt becomes non-resistant when the ground is made slightly more alkaline than that upon which the resistant seed was

originally developed by selection and cropping against a thoroughly wilt infected soil.

On examination of alkaline wheat areas, our experiments show that often what is considered to be fairly alkaline land will produce good growths of wheat if the ground is sterilized or otherwise purified. It is found by experiment that a number of the root fungi which are destructive to wheat and flax develop very much more rapidly in the presence of alkali than in the less alkaline areas. The conclusion drawn from this line of experiments is that very many of the so-called alkaline areas which are now supposed to be too alkaline to produce wheat would be found to grow the crop in good shape if the root-rot diseases were eliminated by proper rotation, proper tillage and seed purification.

16. Ammonification Trials: Some writers have contended that there is a lack of ammonifying power represented in wheat exhausted soils. A rather extended series of trial tests upon this ammonifying power of soils show that it is probable that in the presence of the root organisms the soil which furnishes the least ammonification is apt to have its wheat or flax the least attacked by root fungi. Our trials also show as high ammonifying power on thoroughly wheat-sick and flax-sick soils as is to be found on properly purified or clean lands which no one would call "exhausted."

17. Selection Studies and Disease Resistance: We have conducted selection studies upon various varieties of wheat and various selection strains grown under varying environments of soil and conditions of disease production as affected by soil and by air conditions. Numerous varieties have been held under close check control and grown under careful head row trials and centgener trials so that we could observe the results of the influence of disease upon each individual pedigreed strain year by year. Detailed records have been kept as to the influence of the diseases upon the crop from the time it was planted until harvest. Careful records have been kept as to the weight quality and growth quality of the individual seeds taken from the bulk of the crop and from the individual plants as selected.

In this manner we have been able to draw some conclusions as to whether there is any tendency to the production of more resistant strains of wheat when grown under these trial environments of hard conditions of disease attack. These different selections have always been subjected to continuous disease action through continuous culture conditions, through soil, seed, and plant infection.

From these experiments it is learned that there is great difference in the capability of different varieties and different selection strains to resist disease. Some of them are able to

produce seed when others wholly fail. Different varieties and strains exhibit an evident relation to climatic variations. Some strains do better one year than another. Under certain conditions, certain strains may fail to show any resistance while under other conditions they give a high apparent resistance. This is but another evidence that a variety of wheat grown for a long period under rather permanent conditions tends to adjust itself to such conditions thru the ordinary selective methods of cropping. These selective methods can be intensified and the improvement in the resisting power rapidly developed. It has been much more difficult to get marked improvement in resisting power in the case of wheat than in the case of flax but we have satisfactory evidence that this method of breeding against disease conditions will give lasting results with wheat as it has done in the case of flax and cotton.

WHAT TO DO.

In the effort to get large crops of wheat thru the control of disease, the grower will do well to keep the following facts in mind: 1. **Get a single variety of seed.** It ripens evenly, and hence can be harvested and saved so as to give an even quality of hard dry grains which are less liable to become diseased (moldy) under the bran layers. A pure variety allows of accurate selection of the plumpest, heaviest, most perfect grains, by the ordinary methods of farm selection. Such selection can not be well done in a mixed lot of grain for each variety gives a different shaped grain and demands different screens, wind blast, etc. **The wheat root diseases can not be successfully fought unless the farmers select hard, properly cured, plump, heavy seeds.**

2. **Grade out light weight shrivelled seeds.** Many wheat grains which are shrivelled and of light weight are so because they grew upon root and stem-sick mother plants. They have the disease producing moulds (fungi) already inside. Many big soft light weight seeds are worse than useless because they were wet in the head after maturity, or while in the shock, stack or bin. Such wetting allows the fungi of the root diseases to enter the softened seeds, passing beneath the bran layers. It is practically impossible to properly purify or disinfect soft punky wheat grains so as to free them from root destroying parasites. Screen or Blow them out. Better yet—**Do not let mature wheat which is to be used for seed get wet.**

3. **Disinfect the seed.** Even the plump, heavy, bright colored grains are more or less dusted with the germs (spores) of the wheat-root rots and blights. We have never seen seed so perfect that we could not find some spores of these disease pro-

ducing fungi on some of the grains. Disinfection (seed treatment) not only prevents smut, but helps to prevent the occurrence of the root-blight and rots and tends to prevent soil infection. All seed should be treated every year. It pays. It helps prevent "soil-sickness".

4. Sow thinly on a well prepared seed bed. A plant every three inches in the drill row is sufficient. Poor, disease-infected, shrivelled seeds, thickly seeded soon spoil the best of lands for wheat. They fill the soil with root diseases and compete with each other as grass-like weeds. Virgin or purified lands should give good results with one bushel or less of seed. Do not sow too thick. You want strong roots and heavy grain, not grass or straw. The root diseases spread most rapidly along the drill row in thickly seeded grain.

5. **Rotate.** If the land is already wheat-sick good seed will not help much. **Purify the soil.** This is not hard to do, but it will have to be understood that soil purification means soil disinfection. It means doing something to get the wheat straw and wheat root fungi out of the wheat-sick areas. The first essential is to grow such crops on the land as the wheat fungi (parasites) do not like to grow upon. **Grow some crops there which are not closely related to wheat, as clover, alfalfa, grasses and pasture, corn or potatoes, flax, etc.** The following five reasons for crop rotation in wheat cropping will help to understand this thought: (a) It is a known fact that some rotations tend to produce high quality wheat. (b) As the wheat blight and wheat-root parasites seem to be rather specifically associated with wheat and certain nearly related cereals and grasses, a properly arranged rotation tends to allow the root, stem and seed producing parasites to have a chance to die out before that crop again appears in the series.

(c) A proper rotation involves the use of cultivated crops such as corn, beans, sunflowers, potatoes, beets, mangels, etc. Such crops demand deep plowed soil and constant surface cultivation after the crops are up. Such tillage brings to the surface the spores and growing parts of the wheat-root diseases and other crop blighting parasites where they tend to germinate and die out as do weed seeds. Such constant cultivation also tends to kill off the sort of weeds which are apt to be associated with wheat and cereal cropping, as pigeon grass and quack-grass. Wheat can not grow in the presence of quack-grass because the masses of underground stems which the quack-grass produces become affected by the common wheat-root fungi. Quack-grass is too closely related to wheat. It is often attacked by many of the wheat troubles and helps to intensify them. **Kill off the quack-grass.** If you cannot raise a

cultivated crop every three or four years, a bare summer fallow is a good substitute as a fungus killer.

(d) A proper crop rotation allows one to spread barnyard manures which are made from one kind of crop upon the land which is cropped to some non-related crop. **This is a sanitary measure. Fresh manures containing wheat or barley straw should never be used for top dressing wheat or upon the lands which are about to be used for wheat cropping.** Wheat does not do well in the presence of its own dead bodies. They carry wheat parasites. Spread such barnyard manures on hay and pasture lands or ahead of cultivated crops on the old wheat or cereal stubble.

(e) If a soil is really poor and chances to need a particular artificial fertilizer a properly arranged crop rotation allows one to get the value out of the fertilizers; for, after the ground and seed is properly freed from infectious diseases the roots of the cropping plant can go deeply into the sub-soil and can make use of the plant foods. It will have healthy roots. Wheat plants in wheat-sick soil can not develop roots or stool no matter how much available fertility. Therefore, purify your wheat-sick soil by rotation, tillage and seed selection.

(6) Arrange for Good Drainage. According to the nature of the soil and climate, poorly drained lands either become acid or alkaline. The wheat-root diseases are always most destructive on such poorly drained lands. Either acids or alkalis if above a certain strength of solution at first stunt root growth then cause injuries which are immediately followed by a more intensive or destructive action of the wheat destroying fungi, if such are present. **Drain all such areas.** If acid, liming will usually greatly help. If strongly alkaline, cultivated crops, plus barnyard manures or green manuring will help.

(7) Artificial fertilizers should not be applied until proved to be needed either by chemical analyses of the soil of a particular field or by a special series of pot or plot trials. If, for example, the soils are already alkaline, it may not help matters to add potash, lime, soda, etc. Phosphates on wheat-sick soils have sometimes proven to be beneficial in producing plump wheat. This does not prove that such lands are actually deficient in phosphates but rather that an extra phosphate supply makes an early ripening dry hard stiff straw which tends to prevent the ascent of the wheat-root fungi in the straw. First purify the soil and the seed, then if you fail to get a proper crop and chemical analyses or plot tests show a deficiency of phosphates you will probably have to buy them or change your plan of farm management.

8. Preserve the Purity of your Lands: In using farm-

yard manures in fresh form apply such manures to wheat stubble lands in front of cultivated crops or run the manure spreader over pasture lands. The rains will wash the liquid ammonia and other soluble compounds into the earth and the diseases will gradually die out by aeration and tillage before the next wheat crop is planted. Whenever possible all barnyard manures should be properly composted before being spread. Proper composting kills weed seeds and the spores of disease producing fungi. It is not hard to select an area in which the manure juices can be saved in the compost. Select a clay bottom depression or make a shallow cement bottomed area. Do not use such valuable fertilizer as barnyard compost on old wheat-sick soil if you are going to crop it to wheat; for the nitrogenous juices of the compost will only make a more vegetative, softer straw which is more readily attacked. Such fertilizer also aids the root fungi to spread more rapidly thru the soil. **Barn yard manures in the presence of the wheat diseases means shrivelled grain**, unless it is a very dry year, or an excess of lime, potash and phosphates are present. To get the full benefit of the contents, spread well composted manures on purified lands.

Use all available farm manures, but protect the purity of your soil.

9. Make a proper Seed Bed. A proper seed bed is one in which the water and air can penetrate slowly but deeply. It is so firmly compacted that the moisture comes readily to the top mulch under which the seeds should lie evenly placed. It is so firm that it holds the crop roots at all times well protected from the action of winds, wash waters, frost and sun. Injuries from any of these agencies prevent proper root action and form wounds into which any chance spores or infectious root troubles may enter. A firm under-soil tends to prevent a rapid spread of any fungi which may chance to be in any internally diseased seeds.

10. Harrow the young growing grain freely when the ground is in proper moisture condition, to prevent baking, and to kill weeds and fungi which are weaker than the wheat. The harrowing also tends to conserve the moisture in the soil and further firm the sub-soil on the furrow slice. If air spaces are left between the furrow slice and the sub-soil, these act as damp chambers and the wheat root destroying fungi develop and spread through such spaces with great rapidity, killing the descending roots.

To the old Wheat Raiser: This bulletin contains many statements new to wheat raising. It should be a story of hope. Don't worry about lost fertility. Save what you can. Most of

you have not worn out the mineral fertility of your soil, permanently spoiled its texture, or filled it with toxines poisonous to wheat. You have only been working in an unsanitary manner; and have, by rather constant culture to wheat and its allied plants, introduced into the soil and seed many wheat parasites. Look at the Remedy.

The Remedy Summarized: One Variety of Pure Bred Seed Well Graded and Properly Treated; Infected Lands Purified Thru Right Crop Rotation and Tillage; Purified Farm Manures Applied to the Proper Crops.

H. L. BOLLEY, Botanist.

Agricultural College, N. D.

December, 1913.

INDEX.

Acid Soils and Root Diseases.....	93
Agar Purified Seedlings	30, 37, 40, 41, 42, 43, 49, 67
Alkali Soils, Effect on Seed Deterioration	53, 55, 67, 70, 81, 88, 89
Alternaria	13, 21, 24, 28, 29, 38, 40, 45, 65, 75, 79, 81
Ammonification, Effect of	68, 89
Bedding, Wheat Straw, Effect of.....	4, 5, 25, 69, 79, 87
"Black-Point," Cause of, etc.	5, 10, 12, 13, 55, 61, 69, 72, 74
"Bleaching and Blistering" and Disease	5, 12, 60, 69, 84
"Break-Over" Disease	23, 25
"Brown Spot," Creosote Colored Stem Lesions in Wheat	21, 71
Cephalothecium	82
Characteristics, Diseased Roots In	30, 31, 56, 72, 74, 75
Climate and Soil, Influence on Wheat Cropping	11, 13, 18, 83
Colletotrichum	13, 21, 38, 73, 78
Compost Manures, Effect of	6, 7, 47, 55, 60, 79, 80
Conclusions	35, 41, 51, 71, 74, 83, 88, 90, 94
Constant Cropping, Effect of (Fig. 10)	22, 26, 32, 33, 37, 68, 71
Corn Smut and Soil Exhaustion	16
"Crinkle Joint"	22, 23
Crop Improvement by Selection	6, 11, 19, 20, 87, 90
Crop Rotation, Relation to Soil and Crop Sanitation	5, 6, 7, 28, 35, 45, 47, 51, 62, 82, 85, 87, 91
Crushing Tests on Wheat	37, 61, 84
Culture Conditions, Modern	21
Deterioration, Causes of and Symptoms in Soil and Seed	37, 47, 76, 80, 83
Disease, Distribution of (Figs. 38 and 39)	51, 72, 73, 74
Disease, Garden	68
Disease, Influence of	5, 11, 17
Disease, Resistant Selection Studies.....	17, 89
Disinfectants, Effects of	6, 43, 52, 77, 91
Distribution of Root Diseases	7, 51, 52
Drainage and Wheat Diseases.....	53, 92
Drifting, Distribution of Parasitic Fungi by Winter Winds.....	7, 59, 73, 74
Fairy Rings, Cause of	76, 78
Fertility Lost	3, 6, 7, 27, 31, 39, 59, 61, 80
Fertilizers, Effect on Wheat Fungi (Table).....	5, 6, 7, 29, 55, 61, 66, 68, 77
Fertilizers, Effect on Flax Fungi	64, 78, 79
Flax Diseases, Compared With Wheat Diseases.....	6, 48, 64
Flax, Resistant and Non-Resistant Compared	65, 84, 88
Flax in Rotation With Wheat	85
Flax and Soil Exhaustion	35, 63, 64
Formaldehyde Treatment, Effect of	61, 64, 66, 76, 81, 82
Fungi, Drifting of	35
Fungi, Internal in Straw and Seed	13, 21, 24, 30, 76, 79
Fungi, Wheat Blighting (Fig. 21)	38, 65
Fusarium	13, 21, 24, 34, 38, 40, 46, 65, 73, 82
Inoculation, Effect of	40, 42, 43, 44, 46, 51, 86, 87
Internal Diseases, Effect on Stooling	17, 26, 56, 70, 81
Introduction and Acknowledgment	3-4
Helminthosporium	13, 21, 24, 36, 38, 40, 46, 65, 82
Macrosporium	24, 29, 65, 73, 82
Manure, Fresh, Relationship to Wheat Diseases.....	5, 6, 7, 41, 45, 49, 77, 80, 92
Milling Test	85
Moisture, Relation to Internal Seed Diseases	6, 13, 44, 86, 90
Native Sod, Infection of	72, 76, 78
Nature of Wheat Plant	13

INDEX—Continued.

	Page
Nitrogenous Soils, Effect on Wheat Diseases.....	12, 35, 36, 39, 41, 81, 93
Non-Related Crops in Rotation	85, 91
Old Wheat Lands vs. New Wheat Lands	28, 41, 43
Origin of the Wheat Plant	9
Phosphates, Effect of	11, 32, 39, 62, 64, 66, 80
Piebald Wheat	5, 43, 55, 61
Potato Scab and Soil Exhaustion	15, 35
Pure Cultures, Wheat Destroying Fungi (Figs. 19, 20)	34, 36, 45, 87
Quack-Grass, Effect on Root Diseases of Wheat	59, 91
Remedy	94
Re-Rooting of wheat	25, 31, 56, 75
Research, Original	31, 61
Resistance to Disease	89
Root Diseases, Effect on Young Plants	20, 22, 26, 30, 31, 56
Root Fungi, Mode of Attack on Young Plants and Straw	26, 28
Sanitation and Wheat Deterioration	3, 7, 34, 35, 36, 51
Seed Bed and Plant Disease	93
Seed Blighting Fungi. Mode of Attack on Tissues, (Figs. 14, 15.)	27, 28, 37
Seed Deterioration, Cause of	27, 32, 53
Seed Deterioration on New Lands	21, 27, 41
Seed Treatment, Disinfection and Purification.....	6, 8, 17, 65, 67, 77, 90
Seed Exchange, Influence of	16, 21
Seed, Heavy vs. Light Weight, Effect of Diseases.....	6, 59, 62, 71, 75
Seed, Home Grown, Effect of	18, 20
Seed Infection	60, 76
Seed Selection By Means of Disease Inoculation	86, 87, 89
Seedling Purification, Effects on Stooling	5, 17, 25, 29
Seedling Purification Methods	16, 17, 18, 19, 30, 32, 43, 67
Snow Drifts and Root Diseases	73, 74
Soil, Composition of	11, 39
Soil Exhaustion and Smut	18, 24, 37, 47
Soil Purity	6, 38, 51, 54, 55, 67, 92
Soil Purification, Effect of.....	19, 43, 44, 48, 50, 51, 56, 62, 64, 67, 68, 70
Soil Sanitation, A Complex Problem	6, 7, 34, 35, 49, 51
Spores, Root and Seed Blighting	7, 38
Statement of Wheat Cropping Conditions.....	5, 9, 33, 39, 47
Steaming, Effect of in Crop Weights.....	49, 50, 52, 54, 55, 56, 67, 70
Stooling, Affected By Root Fungi	5, 17, 25, 42, 43, 53, 58, 59
Straw, and Stubble, Effect of	4, 5, 25, 29, 69, 74, 79, 81, 86, 87
"Sun-Scalding," in Young Wheat	5, 37, 44, 53, 57, 67
Survival of Fittest in Breeding	71, 86
Symptoms, Specific	5, 25, 33, 37, 39, 43, 52, 56, 72
Threshing Machine, Effect of	72
"Tip-Burn" in Wheat	5, 20, 37, 44
Tillage, Effect of	5, 91
Types of Wheat	13, 17
Varieties of Wheat, Influence on Cropping	10, 15, 61, 83, 85
Weather and Climate, Effect of	67, 85, 86
Wheat-Sick Soils, Fungi of, etc.	5, 6, 39, 49, 57, 80, 81
Wheat-Sick Soils, the Remedy	90, 94
Wind, Drifting of Spores	5, 7, 72, 73, 74
Winter Wheat, Effect of	18, 69, 74
Wheat-Root Diseases, What to do	35
Wheat Deterioration	3, 39, 43
Wheat Diseases, Effect of Feeding Wheat Straw on	9, 78
Wheat Plant, Origin of	9
"White-Bellied" Grains	43, 55, 69, 74
Yields, Deterioration in, Due to Disease.....	29, 32, 41, 49, 55, 67, 83

North Dakota Agricultural Experiment Station

Avian Tuberculosis

By L. Van Es and A. F. Schalk

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AVIAN TUBERCULOSIS

by

L. VAN ES and A. E. SCHALK

With the acquisition of a more precise knowledge of the disease tuberculosis in general, it soon became apparent that this plague is by no means confined to the mammalian species but that it also claims its victims from among the birds.

The reports of its existence among chickens and turkeys are too numerous to mention. In domesticated water-fowls, the disease is less common. It is described in ducks by King (134), in geese by Husz (121) and Glamann (101), while Cadiot (39) records a case in the swan. Hoskins (118) observed the disease in pigeons and Hobday (116) mentions it as occurring in the ostrich.

Among the authors who called attention to the occurrence of tuberculosis among parrots, we mention Cadiot (35), Cadiot, Gilbert and Roger (41), Strauss (260) Eberlein (85) for the earlier period and Weber, Titze and Weidanz (284) for a later one. The latter also described the disease in canary birds.

The observations of Shattock, Seligman, Dudgeon and Pantou (244) and of Koch and Rabinowitsch (146) make it apparent that the wild birds kept in captivity succumb to tuberculosis with readiness. This includes also the pheasants as evidenced by Bierbaum (21), Morse (186) and one observation by one of the writers.

We know little of its existence among free wild birds. It is probable that it occurs among such scavengers as the common sparrow. The writers observed a well marked case of tuberculosis in a sparrow which had access to an infected poultry yard and could prove the great susceptibility to tuberculosis of sparrows by feeding experiments. A tuberculous sparrow is also mentioned by Metschnikoff (174) but it is not clear whether this was a bird in captivity or not.

HISTORIC CONSIDERATION

As the disease occurs in our domestic fowls, it must have attracted attention a long time ago, although the writers fail to find any evidence of this in the earlier veterinary literature. As late as 1868 Villemin (276) wrote: "There is nothing more problematic than the existence of tuberculosis in the birds." It was not until four years later that its similarity to the disease of mammals attracted atten-

tion and Paulicki (211), quoted by Koch and Rabinowitsch, was the first who gave expression to what he thought about the matter in the following remarks:

"The course of the disease, but especially the manner of dissemination of the abnormalities found, reminds one of tuberculosis of man and mammals, while the microscopic structure and the macroscopic appearance of the tumors show much that corresponds with the pearl disease swellings of the ruminants."

"One, I believe, will not go too far by stating, that the changes found are for the birds what caseous pneumonia and milliary are for man and monkeys and the pearl disease nodules for ruminants or in other words that the consumption of birds is based upon the development of dense, often very extensive tumors in the various organs. It would be of great importance to determine experimentally, if these tumors can be caused to appear by the injection of cheesy masses taken from man."

It was not until the causation of tuberculosis in man and other animals had been brought to light by Koch, that the disease of birds became fairly well recognized and understood. Ribbert (230) was the first one who after Koch studied the character of avian tuberculosis, who pointed out its parasitic character and who suggested the identity of its bacillus to the one discovered by Koch.

After that time the disease and its nature became more widely known, through numerous investigations and reports, until at the present time, it is perhaps the best known of all poultry diseases.

GEOGRAPHIC DISTRIBUTION

A review of the literature of avian tuberculosis shows distinctly that the disease is observed practically in every country where poultry is being raised. According to Theiler (263) it is even widely distributed on the farms of South Africa, although the disease among native cattle and hogs is so little known that the Boers have even no name to designate it.

In this country, fowl tuberculosis attracted but little attention until Pernot (214) described it as occurring in Oregon in 1900. This was followed by reports from California by Moore and Ward (184), from Canada by Higgings (109), and Edwards (86), from New York by Burnett (28), from Nevada by Mack (161), from Minnesota by Beebe (18), from Michigan by Giltner (100), and from Wisconsin by Hastings and Halpin (104).

In North Dakota, the disease has a fairly wide distribution. We have no positive evidence of the existence of the disease prior to the latter part of 1907, although certain inquiries seemed to indicate that it was present. Since the time mentioned, however, we have identified the disease in material sent from twenty-three different localities of the state, without speaking of a considerable number of inquiries, which were not accompanied by specimens and which in a more or less distinct manner permitted the suspicion, that fowl tuberculosis engaged the attention of the correspondents.

ECONOMIC IMPORTANCE

There is no evidence upon which to base a reliable calculation regarding the actual damage inflicted by tuberculosis in our poultry yards. Dawson (66) writing in 1898 still regarded the disease as comparatively rare. Since that time, however, it has become quite apparent, that in tuberculosis we must recognize one of the most prevalent diseases of poultry. There are also numerous indications which point to the great destructiveness of the disease, after once it gains a foothold in a flock. Moore and Ward (184) quote an outbreak in which 300 fowls were lost in a flock of 1460. Tillman (264) mentions a loss of over 200 fowls within a period of three years. In another outbreak, mentioned by Ward (278), 250 fowls out of a flock of 1400 were lost within the period of one year. Edwards (86) reports that a farmer lost fifty fowls in seven months, while two others stated, that they had lost a hundred birds in two years. Hastings and Halpin (104) observed an infected flock of which they estimated that one-third of the number succumbed to tuberculosis in six months and in another outbreak they believed that one-half of the birds were lost in the time of one year. The wide distribution of the disease, combined with its high rate of mortality, should cause us to regard it as a factor to be seriously considered by all those, who follow poultry raising as a part of their farm activities.

In connection with the economic importance of the disease we made some inquiry regarding its possible influence upon the egg-laying capacities of the fowls.

The poultry department of this station kindly placed at our disposal the complete records of egg-laying by all the fowls which were subjected to autopsy in the course of our investigations.

The average number of eggs laid by the various groups of fowls are given in the following table:

EGG LAYING AVERAGES OF NORMAL AND TUBERCULOUS FOWLS.

Fowls With:	Fowls Hatched 1909				Fowls Hatched 1910				Fowls Hatched 1911				Fowls Hatched 1912			
	Year of Egg Laying		Year of Egg Laying		Year of Egg Laying		Year of Egg Laying		Year of Egg Laying		Year of Egg Laying		Year of Egg Laying		Year of Egg Laying	
	1st	2nd	3rd	No. Fowls	1st	2nd	No. Fowls	1st	2nd	No. Fowls	1st	No. Fowls	1st	No. Fowls	1st	No. Fowls
No Lesions	139.00	121.25	79.00	4	101.50	64.00	8	116.15	58	131.77	26					
Lesions I	132.20	135.77	86.33	9	113.39	101.56	23	149.42	7							
Lesions II	145.40	116.40	75.40	10	113.46	87.15	13	94.50	4							
Lesions III	129.60	132.60	83.60	5	124.93	94.13	15	128.00	7							
All Lesions	138.00	130.83	81.95	24	118.76	95.70	51	128.88	19							

In grouping the fowls on which the observations were made, we made provision for normal birds, birds with very slight lesions (Lesions No. I), birds with marked although not extensive lesions (Lesions No. II), birds with extensive lesions (Lesions No. III), while finally the average egg laying performances of all infected birds were also placed in the table.

As certain epidemiological evidence in connection with this outbreak seems to indicate that the flock did not become infected before 1910, the averages of the eggs laid before that year probably only indicate normal fluctuations and should therefore not be regarded as being influenced by disease.

While the numbers of the fowls from which the averages were taken are too small to permit of final conclusions, the tables clearly indicate that tuberculosis does not seem to interfere materially with the egg-laying qualities of domestic fowls. On the contrary, it seems that the egg averages were somewhat higher for the tuberculous birds than the normal ones. Whether this is to be attributed to an increased fecundity induced by the infection or to the fact that the drain of egg-laying renders the animals more susceptible cannot be determined from our material.

ETIOLOGY

As the cause of tuberculosis in all animal species, the microorganism, now extensively known as the *Bacillus tuberculosis*, has been definitely identified. Its general biologic characteristics, as well as the reactions following its introduction into the body of susceptible animals, render it quite apparent that this microorganism constitutes a specific entity, notwithstanding certain opinions to the contrary.

Those opinions are based upon the fact, that the organism presents certain characteristic features varying with the animal species in which it was found to have given rise to the disease. So we find, that the bacillus, associated with tuberculosis in man presents certain characteristics, different from the ones belonging to the organism associated with the disease in cattle. As we study the bacillus of avian tuberculosis, we also note certain marked features by which it can be differentiated from the strains of mammalian origin. In fact, the differences between the avian bacillus and the latter are far more marked than between those of human and bovine origin. This is the reason that even now, the avian bacillus is occasionally mentioned as a species distinct from the ones of mammalian origin. This is largely based upon the fact that the avian bacillus often failed to produce disease when inoculated into

mammals and because the mammalian bacillus when injected into birds quite commonly fails to provoke the formation of tuberculous lesions in the latter.

We cannot go so far as to accept the view that the bacillus of avian tuberculosis is specifically different from the ones found to cause tuberculosis in mammals. We recognize in the avian bacillus and the human and the bovine ones, varieties and strains of one and the same species. That each one of those strains has certain variety peculiarities, especially in its capability of producing disease in various species, must be admitted, but we believe that this feature has a parallel in the case of varieties of higher plants, of which some will thrive in a given soil or climate, while the others will succumb there, but live under such conditions as would destroy the former.

By far the greater part of all cases of avian tuberculosis are caused by the avian type of tubercle bacilli. In shape, not materially different from the types found in the mammals, the organism presents itself as a very small rod, which, however, has a tendency to show certain variations in form.

Usually the avian bacillus shows a tendency to be rather short and somewhat thick in comparison to its length, although in several lesions of avian origin, the authors could show beautifully slender forms. The bacillus of bird tuberculosis shows furthermore a greater inclination towards so-called involution forms than the one of mammalian origin. Especially in those taken from cultures there may occur in one microscopic field a great variety of forms, such as slender, straight, curved, short, plump, club-shaped, and occasionally thread-like branched ones. In structure the organism often shows a granular structure.

They take the carbol-fuchsin stain with great readiness and show their acid fast characteristics in the same manner as the bacilli of mammalian disease.

It can be readily grown upon artificial media and shows a more rapid growth than the organisms of the mammalian tuberculosis.

The media used for the cultivation of the avian tubercle bacillus are those which are also in use for the growth of mammalian bacilli. They are agar-agar, potato, serum, bouillon, egg medium and any such modifications of the same as may be suggested by the fancy of various workers. The addition of from four to six per cent. of glycerine to the media mentioned certainly favors the growth of all the varieties of tubercle bacilli and the avian is no exception to this rule.

The latter shows a rather marked difference from the mammalian types in as much as it is able to grow at much higher temperatures. While both the human and the bovine types cease their growth when the temperature exceeds 40 degrees Centigrade, the avian bacillus still thrives when the latter reaches 45 degrees Centigrade, while even at 50 degrees Centigrade, the development is not fully suspended, even if the resulting cultures are no longer true to type.

This fact was first noted by Nocard and Roux (200), who also called attention to the peculiarities noted in the growth of the avian bacillus. Most of the avian strains are characterized by a smooth moist and more or less slimy growth on the solid media in which they differ from the cultures of mammalian bacilli, which have a tendency to be dry, raised, scaly or corrugated.

Grown on glycerin serum they show in about ten days colonies of the shape of small white waxy spots, which enlarge in size and become confluent to form a whitish scum which can be readily removed from the medium. In the older cultures, the growth becomes more slimy and of a somewhat fibrous texture, at the same time assuming a yellowish color.

In liquid media, such as glycerin-bouillon, they have a tendency to grow in the shape of a fine whitish powder, which fastens itself to the sides and the bottom of the flask and often forms a white pellicle on the surface. This pellicle may have a somewhat dry appearance in older cultures. The avian bacillus seems more capable to grow in the depths of liquid media than the one taken from the mammals.

While the features presented by avian cultures may be looked upon as characteristic of this variety of tubercle bacilli, we must recognize the fact, that they are by no means of constant occurrence.

It was pointed out by Weber and Bofinger (283) that there are strains of avian tubercle bacilli, which like those of mammalian origin form upon solid media a dry, corrugated and upon liquid media a decided surface membrane.

Koch and Rabinowitsch (146) after summarizing the results of a very exhaustive study on the subject concluded that the morphologic and staining features of the avian tubercle bacillus, not alone present nothing constant and typical in the way of differing from the mammalian strains but that the same is largely the case in its behavior in cultures. In the course of a study of ninety-five different strains of avian bacilli they could record a complete series of types of growth, beginning with the typically moist, slimy growth of the cultures to the

dry, scaly appearance peculiar to the mammalian strains. Aside from the majority of typically growing avian varieties these authors met with a number, which varied from the ones true to type, without at the same time approaching the disease producing peculiarities of the mammalian types.

Bongert (23) also throws doubt upon the constancy of the culture characteristics of the various strains of tubercle bacilli, while the observations made by Carl (49) led him to conclude that there are strains of chicken tuberculosis, which in culture closely resemble those of the human type.

The authors could also observe, how cultures of two strains of avian bacilli, which originally showed the growth characteristics typical of this variety, assumed the features of cultures of mammalian types after about ten passages upon glycerine bouillon and at an incubation temperature of 38 degrees Centigrade.

The avian tubercle bacillus is very virulent to most of the birds and especially to the domesticated species. Artificial infection succeeds best by direct inoculation into a vein, while intraperitoneal and subcutaneous injections are apt to yield less certain results. By feeding tuberculous material to birds the disease is readily transmitted. Both cultures and fresh material from diseased organs can be used for this purpose; the latter, however, being apparently the most virulent.

In an experiment made by the authors in order to determine the susceptibility of the common English sparrow to infection by chicken tuberculosis, twelve sparrows were fed one meal of chopped tuberculous chicken liver. All the birds died with generalized tuberculosis, two after 73 days, two after 75 days, one after 100 days, one after 104 days, one after 105 days, one after 118 days, one after 128 days, one after 131 days, one after 186 days, and the last one after 202 days.

The avian bacillus is very resistant to external influences. A contaminated poultry yard may remain infected for a long period after having been vacated by the diseased birds. Kitt (136) found that cultures, which were kept in moist storage were still virulent after one or two years. The action of the ordinary disinfectants upon tubercle bacilli is also rather slow, but heat readily kills them. They are not destroyed by low temperatures. Direct sunlight on the other hand destroys them in a few hours, but is only active on the surface of the material exposed.

To what extent tuberculosis in fowls is due to infection by bacilli of mammalian origin is very difficult to ascertain. It is probable that in exceptional cases this actually takes place

under natural conditions. In the case of parrots, it is a rather common observation. Cadiot and Roger (37) in 1894 concluded that parrot tuberculosis is due to the mammalian type of bacillus, while the observations of Eberlein (84) distinctly point to a direct infection of parrots by tuberculous persons. Delbanco (76) states that the infection of parrots is liable to occur by kissing and feeding of food chewed by infected people. Weber, Titze and Weidanz (284) found that the bovine bacillus was the most virulent to parrots and that the human and avian types followed in the order named.

In other birds of domestication the infection from mammalian sources does not seem so well established, although numerous observations have been published in support of this origin of avian tuberculosis.

In this respect infection by sputum of consumptives is either mentioned or hinted at by Devillers and Lenglen (79), Johne (129), Bollinger (22), Chelkowsky (52), Mollereau (180), Nocard (197), De Lamallerée (74-75), Cagny (48), Durieux (82), Morro (185), Faure (88), Bray (26), Cozette (63), Roger (235), Fritsche (93), United States Bureau of Animal Industry (286) and Darmagnac (65). Human sputum and the organs of tuberculous mammals as causes of avian tuberculosis are mentioned by Nocard (196), Baivy (9), Zschokke (288), Von Behring (19), Romer (234), Kitt (137), Husz (121), Siegl (251), and Arloing (3).

Ordinarily such observations prove but little and the only thing positive, that can be adduced from them, is that avian and mammalian tuberculosis can exist in very close proximity.

When on the other hand several investigators transmitted mammalian tuberculosis to birds experimentally, the casual observations recorded may also be accepted as more or less pointing toward the possibility of a mammalian source of fowl tuberculosis. Even then, however, it cannot be cleared up, whether or not, the infection was due to a pure mammalian bacillus or to an avian one, which had infected a mammal and was transferred back to a bird before it had lost its avian proclivities.

In the experiments carried on with a view of ascertaining the infectiveness of mammalian tubercle bacilli to birds, negative results were often obtained. Koch (144) inoculated two sparrows with a pure culture obtained from the lung of a tuberculous monkey but failed to produce disease. Weber and Bofinger (283) did not succeed in transmitting mammalian tuberculosis to chickens. Of the twelve chickens inoculated with human and bovine material by Jatta and Cosco (126) none

showed any evidence of tuberculosis when killed from eight to ten months afterward. Moore (183) inoculated or fed chickens with human and bovine bacilli and the fowls remained healthy. Weber, Titze and Weidanz (284) could not infect canary birds with bacilli of human origin. De Jong (73) could never secure a tuberculosis in chickens by inoculation with mammalian bacilli. Sometimes the birds would succumb in an emaciated condition after many weeks, but cultures always remained sterile. In other cases he thought to have obtained local tuberculous processes, but no bacilli could be identified in them. Edwards (86) permitted seven chickens to "follow" a herd of twenty-five tuberculous cows and when he slaughtered the birds after fourteen months he failed to find any evidence of tuberculosis. Hastings and Halpin (104) also report negatively on the results of an effort to infect three fowls by means of human sputum.

Zwick (290) reports failure to procure genuine tuberculosis in chickens by either the feeding, by the intravenous, subcutaneous and intra-tracheal injection or by the inhalation of bovine bacilli. It is true that in some of the intravenously injected chickens small nodules were discovered in the lungs and under the serosa of the intestines but these did not contain intact bacilli. Only some acid fast debris was found. In a further publication (291) the same author relates how he first passed a bovine culture into a rabbit and from the latter into a fowl by intra-tracheal injection and that this was followed by pulmonary tuberculosis. Koch and Rabinowitsch (146) report negative results of an attempt to infect chickens and birds of prey with mammalian bacilli. They found, however, that in the case of canary birds, the latter could be infected both by mammalian and avian strains.

Some positive results of the infection of birds with mammalian material are however to be recorded.

Positive results were obtained by Courmont (61) in chickens and pigeons by the use of human bacilli. Cadiot, Gilbert and Roger (40) succeeded in four of the forty-six attempts. Cipollina (53) admits that the human bacillus may cause tuberculosis of the abdominal organs in birds.

Arloing (3) as a result of his experiments concludes that fowls are not resistant to mammalian infection. Bang (12) injected a pure culture of bovine bacilli into two chickens which after one month succumbed to an acute military tuberculosis of the lungs. In a subsequent experiment, this author showed that mammalian bacilli by passage through fowls can be changed to organisms which behave themselves like avia

bacilli and further that an originally bovine bacillus after it has lost its virulence for guinea pigs through repeated passages through fowls is capable to regain its original virulence by passages through mammals.

In another experiment of Bang (11) eighteen different strains of mammalian tubercle bacilli were used and of those it was found that twelve were virulent to chickens. He states, however, that so far as his knowledge goes, mammalian bacilli were never found in spontaneous avian tuberculosis.

Bongert (23) produced tuberculosis in pigeons by introducing pure cultures of the bovine bacillus directly into the respiratory passages.

Koch and Rabinowitsch (146) consider it possible that mice and rats, by their susceptibility to avian tuberculosis may play a part in the spread of the disease in poultry yards.

When we sum up the evidence in regard to the causation of avian tuberculosis, we can conclude that this disease is usually produced by the so-called avian strain of bacillus, but that at the same time, there are certain mammalian strains which are also virulent to chickens and that such strains may occasionally be associated with the causation of the disease in birds.

MODES OF TRANSMISSION AND PATHOGENESIS

As in all other transmissible diseases, the spread of tuberculosis always takes its start, either directly or indirectly from a diseased animal. Tubercle bacilli cannot under ordinary conditions grow outside of the animal body. Avian tuberculosis is no exception to this rule and when it is encountered in a flock, its presence is due to an introduction of the infection from without.

This introduction frequently follows that of new purchases into a healthy flock, and with the great and largely unsupported prevalence of the disease the apparent increase in the number of outbreaks of avian tuberculosis can be readily explained.

But the introduction of infected live fowls, upon the premises is not the only means of transmission of infection. Poultry purchased in butcher shops for table use may be the means of introduction. Trimmings and offal from such fowls carelessly thrown on the garbage pile constitutes an excellent introduction of infection in case the birds were tuberculous.

To what extent wild birds may serve as vehicles of avian tuberculosis in its transmission from flock to flock is not known at this time. As already stated the writers found generalized

tuberculosis in a sparrow having access to a badly infected poultry yard and likewise proved the great susceptibility of sparrows to tuberculosis. They, therefore, made some subsequent inquiry relative to the prevalence of tuberculosis among the sparrows found on the same premises. One hundred and ninety-seven sparrows were examined, but in none was tuberculosis found to be present. While the possibility of sparrows acting as agents of transmission can thus not be altogether excluded, we have as yet no evidence to show that this means of transmission is much to be feared.

It is probable that among the flying birds the domestic pigeon offers more danger in this connection. Veritable outbreaks among pigeons are on record and it can be readily seen, that such birds would constitute a danger to any poultry yard they may habitually visit.

Accepting the available experimental evidence regarding the transmission of mammalian tuberculosis to birds, the writers do not believe that tuberculous man, bovines and swine can be looked upon as important sources of danger for a poultry yard. This is somewhat different in the case of parrots which have shown a high degree of susceptibility to both human and avian bacilli. Parrots and to a less extent canary birds also, may become infected by taking food previously crushed or chewed in the mouth of a consumptive.

In the transmission of tuberculosis from bird to bird, the exit of bacilli from the diseased fowl, as well as their entrance into the healthy birds are the points to be considered. In the light of our present knowledge, we must regard the intestine as practically the only avenue of exit of bacilli. Bacilli are often contained in the faeces in prodigious numbers, although, in not a few cases, it is difficult to find the organism in the bowel discharges.

Edwards (86) made microscopic examinations of the droppings of twenty-nine cases, in which the intestines were tuberculous and found bacilli to be present sometimes in enormous number, while Giltner (100) on the other hand failed to diagnose the disease by the microscopic examination of smears made from fecal matter, secured either by means of swabs taken from the cloaca or from droppings, in spite of the fact that some of the material was badly diseased.

While the exit of bacilli with the faeces is practically the most important means of elimination, the possibility of escape of organisms from open lesions of joints and bones, conjunctiva, skin, etc., must not be forgotten.

In regard to the entrance of infection, the experimental as well as the clinical evidence strongly points to the fact that tuberculosis in birds is usually of an alimentary origin. Other ports of entrance, of course, are possible and no doubt do occasionally play a part, but there is no evidence to show that this happens more than in highly exceptional instances.

In the ordinary course of events the droppings of the diseased birds contaminate the food and water of the healthy ones, which by means of those substances transfer the bacilli to their digestive organs.

While there is no doubt that infection usually takes place in this manner, there seems to be some variation in the speed and constancy of disease production. Weber and Bofinger (283) always succeeded in producing infection in chickens by the feeding of pure cultures of avian bacilli or of organs containing that organism. Edwards (86) fed five healthy hens and two cocks on droppings from tuberculous fowls. In all eleven feeds were given at intervals extending over a period of twenty days. Of the seven birds thus fed, four died within six months and the autopsy proved them to be tuberculous. The remaining three fowls in the course of time died from other causes. The experiments of Giltner (100) do not show that cohabitation surely or quickly results in the transmission of avian tuberculosis. Seven hens kept in contact with tuberculous fowls or in the uncleaned pens previously occupied by them, failed to show lesions after several months. Later tests in which he kept healthy hens in intimate contact with tuberculous ones in advanced stages of the disease failed to disclose transmission after five weeks. Hastings, Halpin and Beach (105) also made an effort to obtain evidence regarding the rate of speed at which the disease may spread in a flock. They obtained nine hens from a diseased flock, four of the nine showing clinical evidence of the disease. These birds were placed with seven hens from a healthy flock. During the first month the birds were kept in a small room, which was not cleaned during that period. After ten, twenty-six and forty-six days, three of the diseased birds succumbed. When the remaining six were killed one year later, all but one were found to be diseased. One of the originally healthy hens was killed after eight months and showed tuberculous lesions. The other birds were killed after the exposure of one year and the autopsy showed that two of the six were tuberculous.

In connection with the transmission in the manner described it is probable that such factors as virulence, number of

bacilli and constancy of their introduction largely determined the nature of the spread of the disease.

Some attention has been paid by a number of investigators regarding the possible transmission of the disease by means of the eggs of tuberculous hens. Koch and Rabinowitsch (146) admit the possibility of a congenital transmission of avian tuberculosis by means of the pre-natal infection of the egg. Maffucci (162) showed that infected embryos may continue to develop. Gärtner (97) inoculated twelve female canary birds and one male into the peritoneum with human tubercle bacilli. In all he obtained nine eggs. They were disinfected with a sublimate solution and their contents injected into the abdominal cavity of guinea pigs. Two of those eggs proved to be virulent. Artault (5) claims to have found tubercle bacilli in market eggs. He examined spoiled eggs for their bacterial contents and for this purpose made subcutaneous injections into rabbits. Among twenty-five inoculations local tuberculosis is said to have developed in two cases. Mohler and Washburn (179) showed that eggs laid by certain tuberculous fowls contained the bacilli in their whites. Higgins (114) also enquired into the danger of infection from this source. Fifteen eggs were received from a flock of fowls among which the disease had been previously diagnosed. Six of these eggs were used for microscopic examination and in three of them, tubercle bacilli were demonstrated without difficulty. Eleven caviars were inoculated with material taken from ten of the eggs, with the result that in two of these animals tuberculosis developed. It seems thus that transmission by means of the eggs must be given consideration, although the data are not sufficiently numerous to enable us to correctly estimate the extent of the danger.

The bacilli picked up with the food find their way into the intestines. Finding suitable ports of entrance in the adenoid tissues of the gut, the organisms either become localized in the structures of the intestinal wall or reach the blood capillaries by which they are conveyed to the portal vein to be finally deposited in the liver or through this organ into the general circulation. It is of common occurrence that the intestinal structures entirely escape damage by the bacilli passing through them, although, it must be remembered that intestinal lesions are very frequently found.

While the formation of the tubercle is the most characteristic result of tuberculous infection, there also occur instances in which the invasion by the tubercle bacilli is not followed by the formation of the classic nodules. In such cases the infec-

tion results in a true tuberculous septicaemia, the tissues are swarming with bacilli but the characteristic lesions are absent. This type of tuberculosis is spoken of as the Yersin type, while that in which the classic tubercle formation is present is known as the Villemin type.

In the latter type, the bacilli localized in the tissues give rise to an inflammatory reaction. There is a proliferation of connective tissues cells and a migration of leucocytes towards the part involved.

As a result a small nodule forms, the characteristic tubercle. This nodule is devoid of blood vessels and in consequence is but poorly nourished. This factor in addition to the action of the toxic substances derived from the bacilli, soon causes degenerative changes to take place in the tubercle under the effects of which the cells of the latter become necrotic from the center outward, a process giving rise to the cheesy granular material so characteristic of tuberculous lesions. In mammalian tuberculosis calcareous material is commonly found in the lesions but in avian tuberculosis, this is comparatively rare.

LESIONS

The unit of all tuberculous lesions is the tubercle. In avian tuberculosis, it does not materially differ from that of the mammalian forms of the disease, although attention has been called to certain differences.

Pfander (215) was the first to devote considerable attention to the lesions of fowl tuberculosis and his descriptions do not materially differ from the ones subsequently given.

He recognizes three types of nodules. He first mentions the tubercle in which caseation has not yet begun and which consists entirely of round, oval or flattened epithelioid cells, surrounded by round cells. These, the youngest tubercles, stand out sharply against the surrounding tissues. The second type mentioned by Pfander are tubercles with beginning caseation. The degenerating cells are stained less clearly and the cell structures finally break down into a colorless debris. In the zone immediately surrounding the caseous material, a layer of intact epithelioid cells may still be seen, as well as a certain number of preserved wound cells in the marginal zone of the tubercle. The third variety described are the larger nodules showing a considerable amount of caseation. The cheesy mass may have become homogeneously hyalin and not infrequently shows concentric stratification.

Around the caseous material a narrow margin of epithelioid cells is found and the latter are frequently flattened by

pressure. They are apt to disappear altogether when caseation progresses. In the older tubercles the cheesy center is commonly surrounded by a connective tissues capsule, a condition also met with in the tubercles more belonging to the second type.

When several large caseous tubercles become confluent they may give rise to voluminous cheesy masses, by which the normal tissues are replaced.

In all three forms of tubercles great numbers of tubercle bacilli can be found.

Among the more conspicuous differences between the avian and the mammalian tubercles, Pfander observed that typical giant cells were rather uncommon in the avian lesions, that the cheesy material of the latter has a tendency to become hyaline in character and that the avian, tubercles are more apt to become surrounded by a connective tissue capsule. Koch and Rabinowitsch (146) found that the lesions described by Pfander in the main correspond to those presented by their own material.

The distribution of the lesions of avian tuberculosis is quite characteristic of the disease.

In the following table the data furnished by Moore and Ward (184), Edwards (86), Vosgien (277), and Hastings, Halpin and Beach (105) are given, while those obtained by the writers are likewise incorporated in the table:

	Author	Moore Ward	Edwards	Vosgien	Hastings Halpin & Beach	N. D. Station
Organs	Autopsies	17	†	145	29	126
		Percent	Percent	Percent	Percent	Percent
Liver		76.47	99.00	98.62	97.00	71.42
Spleen		47.06	92.70	93.10	93.00	58.72
Intestines		35.30	61.20	20.69	60.00	15.87
Lungs		5.88	19.23	42.07	22.00	7.93
Kidneys		17.64	13.04	6.12	10.00	7.93
Bones-Joints		5.88	43.47	22.76	9.00	1.58
Peritoneum		21.17	21.00	8.96	17.00	1.58
Ovaries		5.88	13.00	4.12	14.00	0.79
Gizzard			3.12	.....	.....	0.79
Lymphnodes				70.34	.....	1.58
Conjunctiva						0.79
Skin		5.88	6.52	.....	.....	.....
Heart			2.08	.....	.....	.....

While the data furnished by the various observers indicate, that there are some variations in the distribution of the lesions among the organs, the fact, that in chickens, tuberculosis is essentially an abdominal disease is clearly shown. The



alimentary origin of the disease is in all probability responsible for this phenomenon. While liver and spleen show lesions more frequently than the intestines, lesions of the latter are common enough.

The intestinal lesions of avian tuberculosis are classified by Schern (239) into three types, namely: 1. Smallest nodules in the mucous membrane, without involvement of the serous coat. 2. Lentil sized ulcers with raised edges which caused but little protrusion of the apparently intact serosa. 3. Large nodules prominent on the serous surface, and which form scars in the corresponding mucous membrane and contain in their interior a fine calcareous deposit.

Koch and Rabinowitsch (146), working with material derived from many species, report that they never found the disease in the crop. They encountered it, however, in the gizzard, either in the shape of nodules or ulcers. They look upon the tendency toward tumor formation as quite characteristic of avian tuberculosis. The most extensive intestinal changes were found in the Gallinaceous birds. The entire intestinal tube was found to be studded with numerous nodules covered by the smooth peritoneum. They found nodules up to hazelnut size on any part of the intestine, while those of larger size were more particularly found on the wall opposite the mesenteric attachment. Such nodules, however, were not found beyond the openings of the caeca. Those nodules showed a glassy structure. The mucous membrane over the nodules is commonly intact, but ulcerous ones of all sizes are also found, especially in the case of the larger ones. In such cases, the ulcer presents itself as a saucer-shaped excavation filled with a stratified, yellowish, greenish, necrotic mass. In a smaller number of cases, there are deep, funnel-shaped fistulous ulcers reaching deeply into the nodules and usually characterized by a dirty green color.

As described by Koch and Rabinowitsch, the lesions of the mucous membrane consist of millet seed-like nodules mostly located in the deeper layers of the membrane and shining through in a more or less distinct manner. First of a gray or grayish white appearance, they become more or less yellow with the beginning of the necrosis, project flatly toward the lumen and finally ulcerate. The ulcers so formed have but little tendency to become confluent.

The lesions here described correspond in the main with those found by the authors with the exception, that ulcerations of the intestinal mucosa was comparatively rare in our material. The intestines showed externally isolated or conglomerate

nodules, ranging in size from that of a pin head to that of a pigeon egg. Sometimes those nodules were imbedded into the structures of the intestinal wall, while in other cases they remained attached by means of a rather slender neck or stem. The smaller nodules often had a pearly appearance, the larger ones being more opaque, white or yellowish in color, and of a more solid consistency.

The liver is the organ most commonly involved in avian tuberculosis. The aspect of the liver lesions is largely determined by the extent and age of the infection. In the more recent cases the tubercles are small and when the amount of bacilli thrown into the organ was a small one, their appearance was not very conspicuous. When the opposite was the case, the organ was found to be studded thickly with enormous numbers of smallest tubercles visible alike under the capsule or upon the cut surface. In the older lesions, the tubercles are larger, often conglomerate and surrounded by a more or less well formed capsule, by which they are sharply differentiated from the surrounding liver tissue.

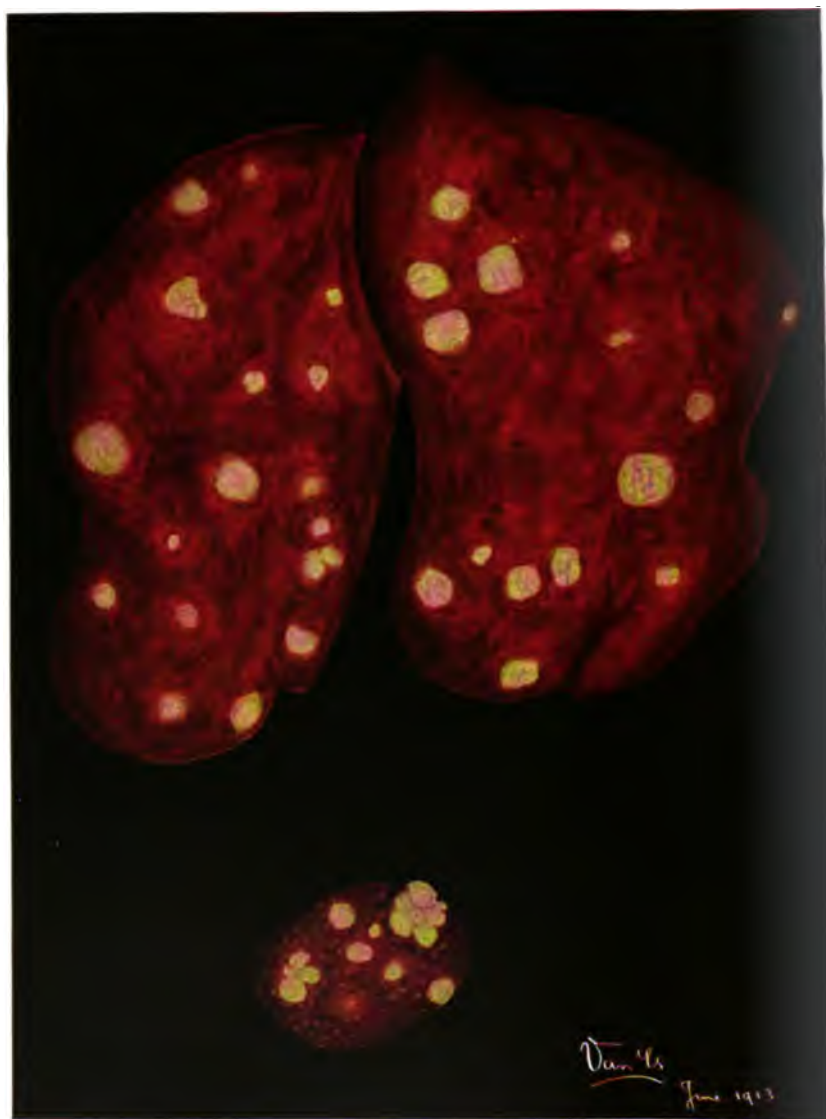
As Koch and Rabinowitsch (146) observe, there commonly is a great difference in the size of the nodules, so that one is readily lead to suspect that distinct bacillary invasions have taken place.

The color of the smaller tubercles is whitish or grayish white and is more in the yellow in the case of the larger and older ones. As in the nodules met in the intestines, the smaller ones are somewhat transparent, while the larger ones are of a more dense appearance.

While the boundaries of the larger nodules are usually very sharply defined, those of the smaller tubercles are commonly quite vague. The larger nodules commonly project from the liver surface and can be readily picked out of the substance of the organ in which smooth cavities are thus left.

Under the influence of tuberculous disease of the liver, the organ is apt to show grave secondary changes. Commonly the same is greatly enlarged, either in its entirety or only of one of the lobes. Degenerative changes are common and often very marked. In those cases the color becomes pale and the tissue exceedingly friable, so that hemorrhages, not uncommonly fatal, are apt to occur during the life of the fowl.

After the liver, the spleen is the organ most apt to show the results of tuberculous infection. The nodules met with in this organ correspond to those seen in the liver, although the conglomeration, as a rule, remains much smaller. The organ often becomes considerably enlarged and distorted.



TUBERCULOSIS OF LIVER AND SPLEEN OF CHICKEN.

Tuberculosis of the ovaries or testicles is not uncommonly seen. In the one case observed by the authors, the ovaries were changed into a large, distorted mass composed of a conglomeration of cheesy or hyaline nodules.

The disease met with in the kidneys by the writers showed very small discreet tubercles, hard and glassy in character and which could be readily separated from the surrounding tissues. It may be worth noting that in several of the cases in which kidney tuberculosis could be observed no evidence of the disease could be found in any of the other organs.

Tuberculosis of the lungs is commonly observed, although the lesions are usually less conspicuous than those of liver and spleen. In most of our cases the lesions consisted of isolated tubercles, of deep yellow color, but in one or two cases, the organs presented a large dense tuberculous mass.

Only in two of our cases could we associate tuberculous disease with lymphnodes, both cases pertaining to nodes situated in the lower cervical region. There was considerable enlargement and the organ was changed into a cheesy mass divided by strips of hard fibrous tissue.

Aside of the lesions found in association with the intestines, the writers could record only two cases of tuberculosis of a serous membrane. In one of those (see Plate I) the mesentery presented a number of hard, dense and milky white nodules, containing large numbers of tubercle bacilli.

Koch and Rabinowitsch (146) state that lesions of the costal pleura occur. In view of the intimate connection between the lungs and the thoracic wall in birds, the process is usually limited to the lateral inner surface of the sternum or the costal articulations.

The tuberculous process is complicated by the exudation of a solid, fibrinous exudate and often extends to the upper part of the peritoneal sack. It usually consists in the formation of flat partly confluent nodules. They also describe the independent development of such nodules on the parietal peritoneum accompanied by the presence of numerous nodules in the mesentery and under the fibrous covering of the intestines. In rare cases, this amounts to the formation of free level, nodular formations on the surface, which are largely composed of tuberculous necrotic granulation tissue. Glamann (101) reporting a case of tuberculosis in a goose describes a peculiar condition of the pleura. This membrane was covered with numerous lentil-sized, flat, pedunculated appendages. They were of a brown color and upon section showed small whitish-

yellow foci of a cheesy or solid consistency. The lesions contained the tubercle bacillus.

Bones and joints are commonly seats of lesions in avian tuberculosis, although only two of our cases showed such lesions. The parts more commonly affected are the knee, hock, digital and shoulder joints. The extremities of the bones gradually enlarge and upon section we meet with a cheesy debris. Occasionally the parts ulcerate and discharge a caseous material rich in bacilli.

Skin lesions were not met with among our material. Basset and Coquot (14) describe a case in which the neck, from which the feathers had dropped out was covered by a voluminous, brown, dry, horny mass, which loosened in an irregular manner. The material laid loosely upon the living tissues and was separated from the same by a thick, cheesy, yellowish white, slightly moist substance. The surface is warty and covered with flesh-like nodules, showing a tendency to become necrotic. The thickness of this granulating membrane is quite considerable in certain portions and presents opaque, cheesy tubercles, containing many bacilli.

In parrots skin lesions seem to be more common. According to Eberlein (84) tuberculosis of the skin and subcutis, as a rule, results in tumor formation. Favorable seats of infection are the corners of the beak and the eye lids. The tuberculous tumors on account of keratization of the superficial layers often have a rough appearance, while deeper down caseation may take place. Irritation caused by scratching and rubbing may give rise to shallow tuberculous ulcers.

Hutyra and Marek (124) state that tuberculosis of the skin and subcutaneous connective tissue in parrots shows itself by the occurrence of spherical or ovoid nodules or tumors, ranging in size from that of a pin head to a hen egg and of a dense or soft consistency. They have a smooth surface and later on undergo caseation. The surface epithelium becomes horny and forms, thick, bark-like layers or horny growths of considerable length. Similar growths may occur in the mouth, the nose or the eyelids.

Law (152) quoting Jewsejenke mentions tuberculous lesions of the lower eye lid of birds and manifested by hard, round, knots covered by a bluish red or yellowish red skin. The writers observed tuberculosis of the conjunctiva in one case. The agglomeration of hard yellowish white tubercles of millet seed size could be readily seen to push the lid outward.

Nocard (202) states that such lesions of the mouth, pharynx, sinuses, nose and conjunctiva as are usually consid-

ered to be caused by roup, were found to be swarming with tubercle bacilli. The writers, however, have reasons to believe, that such findings would be extremely rare in this part of the country.

SYMPTOMS

The symptoms presented by fowls suffering from tuberculosis are very vague and indefinite. Only, when the disease has reached an advanced stage or when the lesions are associated with organs externally situated may the symptoms be sufficiently characteristic to lead to the recognition of the disease.

The latter stages of the disease are commonly marked by an extreme loss of flesh, accompanied by dullness, a roughness of the feathers and paleness of comb and wattles. When handling the birds, their marked lightness becomes at once apparent and the owners of tuberculous poultry will commonly complain that their fowls are "going light."

The loss of flesh is especially noticed when in such cases the muscles of the breast are examined. In many cases it seems that the meat has entirely disappeared and the outline of the breast bone can be distinctly seen or felt under the skin. In a few cases, in which the abdominal organs are the seat of tumor-like lesions the latter may occasionally be felt through the thin, attenuated abdominal walls. Animals affected with extensive tuberculosis usually die in an extremely emaciated condition. Only occasionally do we meet with fowls having extensive tuberculosis, and in which the condition of the body approaches that of normal health.

Occasionally the lesions pertain to such parts as bones and joints, the skin, eye lids, mouth, etc., and then the symptoms produced may be clear enough for a prompt recognition of the disease. When bones or joints are affected, the animal limps or drags one or both wings and a closer examination will reveal a distinct enlargement of the affected parts. Sometimes this is accompanied by ulceration and the escape of a cheesy material.

Symptoms associated with the skin or the visible mucous membranes are very rare among ordinary farm poultry but are more commonly seen in parrots.

DIAGNOSIS

It can be readily understood that in a disease in which characteristic symptoms are so manifestly in default the diagnosis offers great difficulty. Even when there are clear cut disturbances, it is not always possible to attribute them to tuber-

culosis. Wasting disease may be due to other pathogenic factors and the swellings of bones and joints are readily confused with those produced in gouty arthritis or "bumble-foot."

When lesions are near the body surface, their contents may be examined for bacilli, the finding of which, of course, definitely settling the diagnosis. The same may be done with the body discharges in which the bacilli are often present in great numbers. This, however, does not seem to be a constant feature as Giltner (100), for instance, failed to find bacilli in smears made from fecal matter secured from badly diseased fowls.

Whenever it merely is a question relating to the presence or absence of tuberculosis in a given flock, we can have recourse to autopsies on birds killed for the purpose. Such methods, however, will not be of any avail when we desire to determine the condition of a living bird. In mammalian tuberculosis, the specific reaction to tuberculin enables us to recognize the existence of the disease in a given animal with a high degree of accuracy, but in the birds definite tuberculin reactions were not observed until quite recently.

Efforts to diagnose avian tuberculosis by means of tuberculin were made soon after its discovery by Koch. Babés and Babés (8) in 1891 and Diem (80) in 1892 reported that chickens do not react to tuberculin. In 1895, Nocard (202) mentions the test as a possible means of diagnosis but as he does not refer to any evidence in support of its practical value, it is probable that the mention was made on theoretic grounds only. Straus (254) in the same year found that fowls do not react. Ward (279) published the results of tuberculin experiments made with twenty-two fowls during 1904. He worked with three tuberculin preparations, including one of avian origin, but the experiments failed to demonstrate any marked thermic reactions. Moore (183) states in 1906, that tuberculous chickens gave no reaction to tuberculin, not even when an avian product was used, Saalbeck (236-237) writing in 1909, also concluded that tuberculin cannot be used for the diagnosis of tuberculosis in living domestic fowls when applied subcutaneously, in the eye, or cutaneously. In the following year, Klimmer and Saalbeck (142) state that chickens and turkeys, non-tuberculous, tuberculous or infected with human and bovine bacilli gave no reactions to different tuberculin preparations, when applied subcutaneously, ophthalmically or cutaneously.

In 1911 Edwards (86) also published that in both healthy and tuberculous fowls, there was no reaction of temperature

following the injection with tuberculin. Giltner (100) reported in 1912 that he made an avian tuberculin and tested its action by injection into the comb and by instillation into the conjunctival sack, but failed to obtain results. Negative results were also obtained by Higgins (115) who tested tuberculous chickens by means of a special tuberculin, dropped into the eye and injected intradermally.

With a view of enlarging our knowledge in regard to the possibility of applying a tuberculin test in the diagnosis of fowl tuberculosis some experiments were begun at this station in January 1913, using chickens kindly furnished by Dean Shepperd of the Agricultural Division and Professor Dynes in charge of the poultry breeding experiments.

Owing to the negative results obtained by previous investigators when the subcutaneous, ophthalmic or cutaneous method of application was used, the writers experimented almost exclusively with the intra-cutaneous method of tuberculin application introduced by Moussu and Mantoux (188) in 1908 as a practical test in mammals.

Mention should, however, be made of the fact that in some fifty fowls of which a large proportion were actually tuberculous, the ophthalmic test was likewise used, but without any results whatever.

The tuberculin used in our trials was prepared in the customary manner from an avian bacillus and was applied in a fifty per cent. solution. A few trials made with the one hundred per cent. tuberculin brute failed to give better reactions than the weaker solution and its further use was therefore discontinued.

That it is advisable to use avian tuberculin for the testing of chickens is clearly indicated by the results obtained in Series XVI. The eleven fowls of this series were tested with bovine tuberculin with the result that only two chickens reacted. When, however, one month later the birds were tested with avian tuberculin, an additional three birds reacted. The lesions found in the latter showed that they were, no doubt, diseased at the time of the first test.

As places of injection the comb and one of the wattles were chosen. Making injection in a proper manner is probably the most important feature in the testing technic. The injection namely, must be made quite near the surface, and in such a manner that tuberculin is principally deposited along the stratum Malpighi. Tuberculin injected into the deeper layers of the skin of comb or wattles is lost and even in dis-

eased animals will not elicit a reaction. On the other hand, if the injection is made too superficially, there is danger of it bursting through the epithelium.

In order to make the injections in the manner indicated, a small needle is required and after trying several sizes we found that needles of 26 and 27 gauge are the most suitable. While of course, any small syringe will answer the purpose, it will be found advantageous and convenient to select one of very small calibre.

Especially, when making injections into the comb, we found it difficult to even inject a small quantity of tuberculin into the dense tissues belonging to the integument. By selecting a small calibre syringe, it is possible to exert a greater pressure and thereby secure a better infusion of the tuberculin into the tissues.

The injection technic is, in itself, simple enough; the needle is carefully inserted in the layer indicated and the plunger of the full syringe is slowly pressed in. When the needle is not inserted in the proper place, there will be little or no resistance in pressing the plunger in, but when the needle is correctly placed, a considerable pressure is often required to force the tuberculin into the tissues.

We regard those injections as most properly made when, if considerable pressure upon the syringe plunger is exerted the tuberculin but slowly diffuses into the tissues surrounding the needle point and which may often be plainly seen by an increasing white or yellowish area gradually replacing the customary red color of the parts.

We have made no attempts at regulating the dose as we found that in a properly made injection, the amount is automatically limited by the resistance of the tissues; about so much can be injected but not any more. We find, however, that the amount of tuberculin (fifty per cent.) used per fowl will vary from one-thirtieth to one-twentieth of a cubic centimeter.

In our experiments the results of the injections were ascertained twenty-four, forty-eight and seventy-two hours after the introduction of the tuberculin into the tissues.

If reactions are obtained, they correspond to those seen in the intradermal test in mammals and consist of a local swelling of the part injected. Like in those, we notice in the react-



Tuberculin
Syringe for
Chickens.



HEAD OF CHICKEN SHOWING
POSITIVE TUBERCULIN REACTION
OF COMB AND RIGHT WATTLE.



SECTIONS THROUGH
REACTING AND NON-
REACTING WATTLE
SHOWING VOLUME
OF ENLARGEMENT.

11

ing fowls also a considerable degree of variation in the intensity of the reactions.

In the first of our experimental series, we encountered quite a number of cases in which, a swelling was present at the point of inoculation, but not of sufficient size to warrant them in being regarded as actual reactors. In the later series when some skill at injection was acquired, the doubtful reactors became less in numbers.

From this small indefinite swelling the reaction varies up to quite voluminous enlargement of the part injected. In one case, the thickness of the wattle of a reacting fowl increased from 2.5 m. M. thickness before the reaction to 7 m. M. after the same.

The reaction swelling is not accompanied by hyperemia, in fact, the red color of comb or wattle usually makes way for a lighter color under the effect of the reaction. In the central portion of the swelling, the parts are commonly of a pale yellowish color, while surrounding this the color is commonly of a dirty red occasionally with a greenish tinge. This is especially seen in certain comb reactions, while in wattle reactions, there seems to be more of a tendency toward a soft edematous swelling, marked by diffuse discoloration, ranging from a dirty pale yellow to a dirty greenish cast.

Comparing the constancy in comb and wattle reactions, we find that the latter are most constant. In the cases where data for comparison were available we found that in 4.25 per cent. of the reactors the comb reaction only could be observed, in 21.25 per cent. the wattle reaction alone was present, while both reactions were found in 74.50 per cent. of the reactors.

This apparent advantage of the wattle as a place for injection is probably due to the fact that its looser texture permits a more pronounced swelling to take place as compared with the denser structure of the comb. The latter is especially dense in the male birds and in all such which presented a very good wattle reaction, the one in the comb failed to develop.

In spite of the apparent superiority of the wattle as place of injection, we thought it wise to adhere to a simultaneous comb-injection in order to guard against mistakes arising from faulty injections. Since more skill in the injection technic was developed, it became obvious that the injection into one wattle, using the other as a check, is quite sufficient for practical purposes.

In nearly all our cases the reactions seemed to be most pronounced and clear about forty-eight hours after injection.

Most of them were reduced in size on the following day and on the fifth day after injection they had usually completely disappeared.

For so far as we were able to ascertain the injections never resulted in any general disturbance and the birds appeared to be in the same condition during the reaction as before or after.

We have no sufficient data on the manner of reaction to a second injection after the first one had resulted in a typical one. We only injected two reacting fowls a second time and those again reacted in about thirty days after the first test.

In the following tables the details of the investigation are presented. The negative reactions are indicated by the (—) sign. The positive ones by means of the plus (+) sign, indicating the degree of the reaction by (+) for slight, by (++) for marked and by (+++) for very marked swellings. In the questionable reactions the question sign (?) is generally used, but when this is combined with the minus sign (—?), we indicated that while some reaction is present, it is probably negative, while, on the other hand, it is used with the plus sign (+?), the swelling, while still questionable, was sufficient to warrant the suspicion of it being a positive indication.

The tables likewise show the results of the autopsy whenever the opportunity for making one was given us. The degree of the lesions found are also indicated by the use of the plus sign. Slight lesions are indicated by (+), marked lesions by (++) and very extensive lesions by (+++).

In order to avoid the misinterpretations of lesions, we have ascertained the presence or absence of tubercle bacilli in all cases examined and indicate those findings in a separate column in the usual manner.

SERIES I

No.	Identi- fication	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
1	5902	++	++	+				spleen	++	+
2	18	—	—	—				—		+
3	D. C.	++	++	++				liver	+	
4	7	++	++	—				—		
5	40	—	—	—				—		
6	5937	—	+	+				liver	+	+
								spleen		
7	5710	++	+	+				liver	+	+
8	2	—	—	—				—		
9	4876	—	—	—				—		
10	5713	—	—	—				—		
								spleen		
11	5931	+	—	—				liver	+	+
								—		
12	6154	—	—	—				—		
								liver		
13	6124	—	—	—				spleen	++	+

[illegible]

No.	Identification	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
32	5725	+	+	+				—		
33	5737	+	+	—				spleen	+	+
34	5740	—	—	—						
35	5743	+	+	+				liver	+	+
								spleen	+	
36	5749	—	+	—				liver	+	+
								spleen	+	
37	5901	+	+	+				liver	++	+
								spleen	++	
38	5906	+	++	+				—	—	
39	5910	+	+	+				spleen	++	+
40	5914	—	+	+				liver	+	
								spleen	+	+

41	5918			+	+		spleen liver	+	+	+
42	5922			+	+		spleen liver	+	+	+
43	5923	+		+	+		spleen	+	+	+
44	5928	-		+	+		liver spleen intest.	+	+	+
45	5930	+		+	+		spleen	+	+	+
46	5948	+		+	+		liver	+	+	+
47	5950	+		+	+		kidney intest.	+	+	+
48	6188	+		+	+		liver	+	+	+
49	6755	-		+	+		liver	+	+	+
50	L. R.	-		-	-		-			
51	8538	-		-	-		-			
52	6143	?		+	+		liver	+	+	+
53	6106	?		?	?		spleen	+	+	+
54	6107	?		+	+		spleen liver	+	+	+
55	6115	+		+	+		liver spleen lung intest.	+	+	+

No.	Identification	Reactions						Lesions		
		Comb				Wattles		Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
56	6117	—	?	—	—	—	—	liver	++	+
57	6118	?	?	?	—	—	—	spleen	++	+
58	6119	+	+	+	+	++	++	liver	+	+
								liver	+	+
								spleen	++	+
59	6120	—	+	+	—	++	++	liver	+	+
								spleen	++	+
60	6128	+	+	++	++	++	++	intest.	+	+
61	6130	—	++	++	++	++	++	liver	++	+
62	6131	—	—	—	—	—	—	spleen	++	+
63	6142	—	—	—	—	—	—	spleen	++	+
64	6155	—	+	+	?	+	+	intest.	++	+
65	6156	+	++	++	?	?	?	liver	++	+
66	6164	+	++	+	—	+	—	intest.	++	+
67	6166	+	++	+	—	++	—	kidney	++	+
68	6172	?	?	?	—	—	—	liver	++	+

[illegible]

No.	Identification	Reactions						Lesions		T. B. Findings		
		Comb			IVattles			Organs	Degree			
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.					
83	77	-	-	-	-	-	-	-	-	-	-	-
84	82	-	+	-	-	-	-	-	-	-	-	-
85	84	-	-	-	-	-	-	-	-	-	-	-
86	4878	-	-	-	-	-	-	-	-	-	-	-
87	4879	-	-	-	-	-	-	-	-	spleen	++	+
										liver	+	
88	4881	-	-	-	-	-	-	-	-	-	-	-
89	6116	-	+	+	-	-	-	-	-	liver	++	++
90	6133	-	-	-	-	-	-	-	-	liver	++	
										liver	++	+
91	6141	+	++	++	+	+	+	++	++	spleen	++	
										liver	++	+
92	6161	-	-	-	-	-	-	-	-	liver	++	+
										spleen	++	
93	6170	-	+	+	-	-	-	-	-	liver	++	
94	1	-	-	-	-	-	-	-	-	spleen	++	+
95	3	-	-	-	-	-	-	-	-	-	-	-

96	10	-	-	-	-	-	-	-	-	-
97	35	+	+	+	+	+	+	+	+	+
98	41	-	-	-	-	-	-	-	-	-
99	46	-	-	-	-	-	-	-	-	-
100	8541	-	-	-	-	-	-	-	-	-

REMARKS.

s—Smears from a questionable looking, very small nodule in the liver revealed two acid fast bodies, somewhat resembling TB., but very doubtful as to identity.

°—In the numbers marked °, a 100% tuberculine was used.

*—In birds marked thus *, there were no typical lesions, but the liver contained acid fast bacilli, probably TB.

SERIES II

No.	Identifi- cation	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
^a 101	3	—	—	—	—	—	—	—	—	
^b 102	11	—	—	—	—	—	—	—	—	
^c 103	14R	—	—	—	—	—	—	—	—	
104	14H	?	—	?	—	—	—	—	—	
^d 105	19R	—	—	—	+	++	++	lung kidney	++	+
106	30	+	+	+	++	++	+	liver spleen Intest.	+++ +++ +++	+
^e 107	36	?	?	—	?	?	—	—	—	
108	37R	—	—	—	—	+	+	lung kidney	++ +	+

	+	+	+	+	+	+
43	+	+	+	+	+	+
44	+	+	+	+	+	+
53	+	+	+	+	+	+
58	+	+	+	+	+	+
60	+	+	+	+	+	+
64	+	+	+	+	+	+
68	+	+	+	+	+	+
69	+	+	+	+	+	+
79	+	+	+	+	+	+
80R	+	+	+	+	+	+
83	+	+	+	+	+	+
89	+	+	+	+	+	+

No.	Identi- fication	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
121	90	-	-	-	-	-	-	-	-	
122	4884	-	-	-	-	-	-	-	-	
123	6112	-	-	-	-	-	-	lung	+	+
124	6146	-	-	-	-	-	-	liver	+++	+
125	6165	-	-	-	-	-	-	spleen	++	
		-	+	-	+	-	++	spleen	+	+
126	60	+	+	-	-	-	-	liver	+	+
127	66	+	+	-	-	-	-	liver	+	
128	73	+	-	-	-	-	-	-	-	
129	76	-	-	-	-	-	-	spleen	+	+

130	194	+	?	?	?	+	+	liver spleen intest.	+	+
131	4886	+	+	?	-	+	+	kidney	+	+
132	6105	++	++	++	++	+	++	spleen intest.	++	++
133	6138	++	++	++	++	+	++	spleen	+	+
134	6148	-	-	-	-	-	-	spleen	-	+
135	6150	-	-	-	-	-	-	spleen	-	+
136	6152	+?	-	-	-	-	-	liver	+	+
137	6160	+	?	?	-	+	+	spleen liver intest.	++ ++ ++	+
138	6173	+?	-	-	-	+	+	liver	+	+
139	6190	+	?	?	?	+	++	spleen liver intest. lung	++ ++ ++ +	+
140	6191	++	?	?	-	-	-	peritoneum	++ ++	+
141	6198	+?	+	+	+	+	+	spleen liver	+	+

No.	Identifi- cation	Reactions								Lesions		T. B. Findings
		Comb				Wattles				Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.					
142	6199	+	+	+	+	+	+	+	+	spleen	+	+
143	6754	+	+	+	+	+	+	+	+	Liver	+	+
144	6796	+	+	+	+	+	+	+	+	spleen	+	+
145	7429	+	+	+	+	+	+	+	+	liver	+	+
146	23	+	+	+	+	+	+	+	+	spleen	+	+
147	51	+	+	+	+	+	+	+	+	liver	+	+
148	54	+	+	+	+	+	+	+	+	—	—	+
149	67	+	+	+	+	+	+	+	+	liver	+	+
150	68	+	+	+	+	+	+	+	+	—	—	+
151	72B	+	+	+	+	+	+	+	+	liver	+	+

No.	Identifi- cation	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
167	7393	- ⁹	+	⁹	- ⁹	+	⁹	liver	+	+
168	8505	-	-	-	-	-	-	-	-	-
169	8508	⁹	⁹	-	-	-	-	liver	+	+
170	8518	-	-	-	+	+	-	-	-	-
171	4	-	-	-	-	-	-	-	-	-
172	8	-	-	-	-	-	-	-	-	-
173	c 11	-	-	-	-	-	-	-	-	-
174	19	-	-	-	-	-	-	-	-	-
175	c 20	-	-	-	-	-	-	-	-	-
176	21	-	-	-	-	-	-	-	-	-
177	31	-	-	-	⁹	-	-	-	-	-
178	c 52	-	-	-	-	-	-	-	-	-

[illegible]

No.	Identification	Reactions						Lesions			T. B. Findings
		Comb			Wattles			Organs	Degree		
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.				
195	8539	—	—	—	—	—	—	—	—	—	+
196	13	—	—	—	—	—	—	liver spleen intest. cerv. lyphn.	+++ +++ +++ +++ +++	—	
197	15	—	—	—	—	—	—	—	—	—	
198	16	—	—	—	—	—	—	—	—	—	
199	17	—	—	—	—	—	—	—	—	—	
200	c	—	—	—	—	—	—	—	—	—	
201	24	—	—	—	—	—	—	—	—	—	
202	25	—	—	—	—	—	—	—	—	—	
203	27	—	—	—	—	—	—	—	—	—	
	28	—	—	—	—	—	—	—	—	—	

[illegible]

No	Identifi- cation	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
c	81	-	-	-	-	-	-			
c	83	-	-	-	-	-	-			
c	92	-	-	-	-	-	-			
c	93	-	-	-	-	-	-			
c	97	-	-	-	-	-	-			
c	98	-	-	-	-	-	-			
c	223	-	-	-	-	-	-			
c	224	-	-	-	-	-	-	-	-	
c	225	-	-	-	-	-	-	-	-	
c	226	-	-	-	-	-	-	-	-	
j	227	-	+	-	-	+	-	-	-	+
c	228	-	-	-	-	-	-			

	8513	+ +
	8514	
	8517	
	8520	
	8521	
	8522	
	8526	
	8527	
	8528	
	8529	
	8530	
	8531	
	8532	
	8533	
	8534	
	8535	
	8536	

No.	Identification	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
b 246	8537	— ?	— —	— —	— ?	— —	— —	spleen	+	+
247	8540	—	—	—	—	—	—	—	—	
248 c	8542	— ?	— —	— —	— —	— —	— —	liver	+	+
	8543	—	—	—	—	—	—			

a-101—There are no definite lesions but a few bacilli were found in the perivascular tissues of the liver.
b-102, b-205, b-246—Affected with roup.

c-103 etc.—Returned for breeding purposes.

d-105—The wattle reaction of this fowl was very marked. 48 hours after injection the wattle measured 7m.M. in thickness, while the non-injected wattle only measured 2.6 m.M.

e-107—This fowl was intended for retest but was killed by mistake.

f-116—Acid fast debris in kidney lesions and in doubtfully appearing, whitish areas in spleen.

g-131—The bacilli found in those organs were very short and although acid fast seemed doubtful.

h-152, 180, 181—Died before retest.

i-171—An abundance of acid fast debris in spleen.

j-227—No definite lesions, but smears from liver and spleen contained typical tubercle bacilli.

k-233—Died during retest.

l-236—Died after completion of retest.

SERIES III

No.	Identifi- cation	Reactions									Lesions		T. B. Findings
		Comb			Wattles						Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
250	95	-	-	-	-	-	-	-	-	-			
251	9151	-	-	-	-	-	-	-	-	-			
252	9152	-	-	-	-	-	-	-	-	-			
253	9153	-	-	-	-	-	-	-	-	-			
254	9154	-	-	-	-	-	-	-	-	-			
255	9155	-	-	-	-	-	-	-	-	-			
256	9156	-	-	-	-	-	-	-	-	-			
257	9157	-	-	-	-	-	-	-	-	-			
258	9158	-	-	-	-	-	-	-	-	-			
259	9159	-	-	-	-	-	-	-	-	-			
260	9160	-	-	-	-	-	-	-	-	-			

No.	Identifi- cation	Reactions								Lesions					
		Comb				Wattles				Organs	Degree	T. B. Findings			
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.				72 hrs.		
261	9161	-	-	-	-	-	-	-	-	-	-	-	-	-	
262	9162	-	-	-	-	-	-	-	-	-	-	-	-	-	
263	9163	-	-	-	-	-	-	-	-	-	-	-	-	-	
264	9164	-	-	-	-	-	-	-	-	-	-	-	-	-	
265	9165	-	-	-	-	-	-	-	-	-	-	-	-	-	
266	9166	-	-	-	-	-	-	-	-	-	-	-	-	-	
267	9167	-	-	-	-	-	-	-	-	-	-	-	-	-	
268	9168	-	-	-	-	-	-	-	-	-	-	-	-	-	
269	9169	-	-	-	-	-	-	-	-	-	-	-	-	-	
270	9170	-	-	-	-	-	-	-	-	-	-	-	-	-	

a—All birds returned.

SERIES IV

No.	Identifi- cation	Reactions					Lesions	
		Comb		Wattles			Organs	Degree
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.		
271	9171	-	-	-	-	-		
272	9172	-	-	-	-	-		
273	9173	-	-	-	-	-		
274	9174	-	-	-	-	-		
275	9175	-	-	-	-	-		
276	9176	-	-	-	-	-		
277	9177	-	-	-	-	-		
278	9178	-	-	-	-	-		
279	9179	+	-	-	+	-		
280	9180	-	-	-	-	-	-	-
281	9181	-	-	-	-	-		

No.	Identification	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
282	9182	-	-	-	-	-	-			
283	9183	-	-	-	-	-	-			
284	9184	+	-	-	-	-	-			
285	9185	-	-	-	-	-	-			
a	286	+	+	-	+	+	-		-	
287	9187	-	-	-	-	-	-			
288	9188	-	-	-	-	-	-			
289	9189	-	-	-	-	-	-			
290	9190	-	-	-	-	-	-			

a—All birds returned except those marked thus a.

SERIES V a

No.	Identification	Reactions								Lesions		
		Comb				Wattles				Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.			
291	3575	—	—	—	—	—	—	—	—			
292	9192	—	—	—	—	—	—	—	—			
293	9194	—	—	—	—	—	—	—	—			
294	9195	—	—	—	—	—	—	—	—			
295	9199	—	—	—	—	—	—	—	—			
296	9200	—	—	—	—	—	—	—	—			

a—All birds returned.

SERIES VI

No.	Identification	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
297	47	—	—	—	—	—	—	—	—	
298	88	—	—	—	—	—	—	—	—	
299	95	—	—	—	—	—	—	—	—	
300	4895	—	—	—	—	—	—	—	—	
301	6282	—	—	—	—	—	—	—	—	
302	6283	—	—	—	—	—	—	—	—	
303	6285	—	—	—	—	—	—	—	—	
304	6387	—	—	—	—	—	—	—	—	
305	8545	—	—	—	—	—	—	—	—	
306	8549	—	—	—	—	—	—	—	—	

SERIES VII a

307	89	—	—	—	—	—	—	—	
308	99	—	—	—	—	—	—	—	
309	100	—	—	—	—	—	—	—	
310	6281	—	—	—	—	—	—	—	
311	6284	—	—	—	—	—	—	—	
312	6286	—	—	—	—	—	—	—	
313	6287	—	—	—	—	—	—	—	
314	8544	—	—	—	—	—	—	—	
315	8547	—	—	—	—	—	—	—	
316	8548	—	—	—	—	—	—	—	

SERIES XII

No.	Identifi- cation	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
^a 325	9163				—	—	—	—	—	—

a—This fowl badly affected with mange and died before the completion of test.

SERIES XIII a

326	237									
327	8546	—	—	—	—	—	—	—	—	—
328	3255	—	—	—	—	—	—	—	—	—
329	3260	—	—	—	—	—	—	—	—	—
330	3289	—	—	—	—	—	—	—	—	—
331	3259	—	—	—	—	—	—	—	—	—

a—All fowls affected with chicken-pox.

SERIES XIV a

332	J1	—	—	—	—	—	—	—	—	—
333	J2	—	—	—	—	—	—	—	—	—
334	J3	—	—	—	—	—	—	—	—	—
335	J4	—	—	—	—	—	—	—	—	—
336	J5	—	—	—	—	—	—	—	—	—
337	J6	—	—	—	—	—	—	—	—	—
338	J7	—	—	—	—	—	—	—	—	—
339	J8	—	—	—	—	—	—	—	—	—

a—All fowls affected with chicken-pox.

[illegible]

No.	Identifi- cation	Reactions						Lesions		
		Comb			Wattles			Organs	Degree	Findings T. B.
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
362	9187	-	-	-	-	-	-	-	-	
363	9188	-	-	-	-	-	-	-	-	
364	9189	-	-	-	-	-	-	-	-	
^a										
365	R	-	-	-	-	-	-			
^a										
366	24	-	-	-	-	-	-			
^a										
367	45	-	-	-	-	-	-			
368	49	-	-	-	-	+	+	Liver	++	+
								spleen	+	
^a										
369	52	-	-	-	-	-	-			
^a										
370	54	-	-	-	-	-	-			
^a										
371	63	-	-	-	-	-	-			
^a										
372	68	-	-	-	-	-	-			
^a										
373	83	-	-	-	-	-	-			

[illegible]

No.	Identification	Reactions						Lesions			T. B. Findings	
		Comb			Wattles			Organs	Degree			
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.					
a 390	11R	—	—	—	—	—	—					
a 391	27	—	—	—	—	—	—					
a 392	44	—	—	—	—	—	—					
a 393	55	—	—	—	—	—	—					
a 394	67	—	—	—	—	—	—					
a 395	68R	—	—	—	—	—	—					
a 396	72	—	—	—	—	—	—					
a 397	76	—	—	—	—	—	?					
398	81	—	—	—	+	+	+	spleen	+	+		+
a 399	83R	—	—	—	—	—	—			+		
a 400	89R	—	—	—	—	—	—			+		

+

+

liver

+

+

+

-

-

-

91

401

a

402

a

403

a

404

a

405

a

406

a

407

a

408

a

409

a

410

a

411

a

412

a

413

a

414

a

415

a

416

a

417

a

No	Identification	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
a	3015	—	—	—	—	—	—			
a	3016	—	—	—	—	—	—			
a	3017	—	—	—	—	—	—			
a	3018	—	—	—	—	—	—			
a	3019	—	—	—	—	—	—			
a	3020	—	—	—	—	—	—			
a	3021	—	—	—	—	—	—			
a	3022	—	—	—	—	—	—			
a	3023	—	—	—	—	—	—			
a	3024	—	—	—	—	—	—			
a	3025	—	—	—	—	—	—			
a	3042	—	—	—	—	—	—			

No.	Identification	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
a	6435	—	—	—	—	—	—	—	—	—
a	6439	—	—	—	—	—	—	—	—	—
a	6440	—	—	—	—	—	—	—	—	—
a	6447	—	—	—	—	—	—	—	—	—
a	8506	—	—	—	—	—	—	—	—	—
a	8516	—	—	—	—	—	—	—	—	—
a	8543	—	—	—	—	?	+	—	—	—
a	1856	—	—	—	—	—	—	—	—	—
a	1857	—	—	—	—	—	—	—	—	—
a	1870	—	—	—	—	—	—	—	—	—
a	1872	—	—	—	—	—	—	—	—	—
a	1876	—	—	—	—	—	—	—	—	—

460 1888
461 1886
462 1888
463 1889
464 2901
465 2903
466 2904
467 2905
468 2906
469 2907
470 2908
471 2910
472 2911
473 2912
474 2914
475 2915
476 2916

No.	Identi- fication	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
a	2917	—	—	—	—	—	—			
477		—	—	—	—	—	—			
a	2918	—	—	—	—	—	—			
478		—	—	—	—	—	—			
b	2919	—	—	—	—	—	—			
479		—	—	—	—	—	—			
a	2920	—	—	—	—	—	—			
480		—	—	—	—	—	—			
a	2921	—	—	—	—	—	—			
481		—	—	—	—	—	—			
a	2924	—	—	—	—	—	—			
482		—	—	—	—	—	—			
a	2925	—	—	—	—	—	—			
483		—	—	—	—	—	—			
a	2926	—	—	—	—	—	—			
484		—	—	—	—	—	—			
a	2927	—	—	—	—	—	—			
485		—	—	—	—	—	—			
a	2929	—	—	—	—	—	—			
486		—	—	—	—	—	—			
a	2930	—	—	—	—	—	—			
487		—	—	—	—	—	—			
a	2931	—	—	—	—	—	—			
488		—	—	—	—	—	—			

[illegible]

No.	Identification	Reactions						Lesions		
		Comb		Wattles				Organs	Degree	T. B. Findings
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
5463		—	—	—	—	—	—			
5464		—	—	—	—	—	—			
5465		—	—	—	—	—	—			
5466		—	—	—	—	—	—			
5467		—	—	—	—	—	—			
5468		—	—	—	—	—	—			
5469		—	—	—	—	—	—			
5471		—	—	—	—	—	—			
5470		—	—	—	—	—	—			
5472		—	—	—	—	—	—			
5473		—	—	—	—	—	—			
5474		—	—	—	—	—	—			
5475		—	—	—	—	—	—			
5477		—	—	—	—	—	—			
5478		—	—	—	—	—	—			
5479		—	—	—	—	—	—			
5481		—	—	—	—	—	—			
5482		—	—	—	—	—	—			
5483		—	—	—	—	—	—			
5484		—	—	—	—	—	—			
5485		—	—	—	—	—	—			
5486		—	—	—	—	—	—			
5487		—	—	—	—	—	—			

No.	Identifi- cation	Reactions						Lesions		T. B. Findings
		Comb			Wattles			Organs	Degree	
		24 hrs.	48 hrs	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
^a 579		—	—	—	—	—	—			
^a 580		—	—	—	—	—	—			
^a 581		—	—	—	—	—	—			
^a 582		—	—	—	—	—	—			
^a 583		—	—	—	—	—	—			
^a 584		—	—	—	—	—	—			
^a 585		—	—	—	—	—	—			
^a 586		—	—	—	—	—	—			
^a 587		—	—	—	—	—	—			
^c 588		++	++	+	++	++	++	liver	++	+
^a 589		—	—	—	—	—	—			

a—Fowls returned for breeding purposes.

b—Paralytic chicken.

c—This fowl was retained for retest but was exposed to infection, hence the reaction. The lesions were numerous, small and recent.

No.	Identification	Reactions						Lesions			T. B. Findings
		Comb			Wattles			Organs	Degree		
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.				
590	76	-	-	-	-	-	-	-	-	-	
591	77	-	-	-	-	-	-	liver	+	+	+
592	78	-	-	-	+	++	+	liver spleen Intest. Mesen'y	+++ +++ +++ +++	+	+
598	79	-	-	-	-	-	-	-	-	-	
594	82	-	-	-	+	++	++	liver Spleen Intest.	+++ +++ +++	+	+

No. Identification	Reactions						Lesions		
	Comb			Wattles			Organs	Degree	T. B. Findings
	24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.			
595	-	-	-	?	?	-	liver Spleen Intest.	+++ +++ ++	+
596	-	-	-	-	-	-	-	-	
597	-	-	-	-	-	-	-	-	
598	-	-	-	-	-	-	liver	+++	+
599	+	++	+	+	++	++	spleen	+++	
600	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	spleen	+	+

a—Fowls from infected flock.

b—The first test was made with bovine tuberculin and the test of a month later was made with avian tuberculin.

Summarizing the results of all series we find:

Total number of tests made.....	601	
Number of fowls examined by autopsy.....	277	
Number of fowls with lesions.....	125	
Fowls showing typical reactions.....	90	
Reacting fowls with lesions.....	88	(97.77%)
Reacting fowls without lesions.....	2	(2.23%)

Fowls without lesions	130	
Non-reacting fowls without lesions.....	120	(91.53%)
Non-reacting fowls with lesions.....	10	(8.47%)

Fowls with doubtful reactions	57	
Doubtfully reacting fowls with lesions.....	27	(47.36%)
Doubtfully reacting fowls without lesions....	30	(52.64%)

From the above it appears that the presence of a reaction in the chickens tested is an almost certain indication of tuberculous infection, especially so, when we remember that in one of the two birds reacting, without showing lesions at the autopsy, the liver and the spleen contained a considerable number of free tubercle bacilli.

In our earlier series the indications furnished by the non-reacting fowls were less accurate. At the time we attributed the false indications to faulty injection technic and this suspicion was realized by later experience. In the later series, the negative reactions were nearly always confirmed by the post-mortem findings.

The fact that we could not check the results of the test in all chickens examined, but could only do so in the series most thoroughly infected may also have had its influence in the comparatively large percentage of error in the non-reacting birds.

In addition to the above, we must keep in mind the non-susceptibility to tuberculin in gravely affected mammals and we may believe similar conditions may exist in fowls.

While nothing less than a great amount of practical experience obtained under all kinds of conditions will be necessary to establish the usefulness of the intradermal tuberculin test in the eradication of tuberculosis from farm poultry, the results obtained in our experiments are strongly suggestive of its value.

At first we were somewhat discouraged by the comparatively large numbers of doubtful reactions, but as with the

accumulation of experience the doubtful reactions only occur in less than ten per cent. of the total fowls tested, we no longer believe that they constitute a fatal disadvantage.

In addition to becoming a possible factor in the eradication of avian tuberculosis, the test may likewise become an aid in the various lines of research, dealing with avian tuberculosis, its etiology and relations to the tuberculoses of other species. It would enable the investigator, at least, to a very large extent, to select birds for experimental purposes known to be free from the disease, eliminating in this manner the danger of errors due to spontaneous tuberculous infection.

The writers believe to be fully warranted in recommending the tuberculin test as here described for further trials but cannot do so without calling attention to the fact, that a certain amount of skill and experience in the making of the injections is necessary. This warning should especially appeal to the lay poultry owner, not familiar with the procedures of this kind. We believe it well within the power of any intelligent person, to master the injection technic quite fully, but one must expect some contrary results such as were also encountered by the writers in the earlier series of our experiments.

Especial care must be taken in securing the most superficial injection possible, while in the handling of the wattle, the bruising of the parts must be carefully avoided.

PROGNOSIS

Like many other species, tuberculosis of poultry is essentially a chronic, progressive disease, which with the extension and increase of the lesions slowly leads to emaciation and death. No doubt, we can occasionally find evidence to show that the progress of the disease has been arrested, but in birds this is comparatively rare, and most of the animals affected sooner or later succumb in the manner already indicated. That the disease progresses slowly and that the fatal termination occurs mostly after a considerable time is clearly shown by the fact that the older birds of a flock which became infected sometime in 1910, furnished the higher percentages of actual disease. The distribution of the disease among the birds at various ages as found during autopsy early in 1913 was as follows:

Year when hatched	Percentage of infection
1909	85.71
1910	86.44
1911	24.35
1912	3.33

The fact that the percentages for the birds of 1909 and 1910 are so nearly alike must be attributed to the fact that they very probably became exposed to infection at one and the same time.

Treatment of avian tuberculosis is impracticable and of no value in the control of disease.

PROPHYLAXIS

The prospects of successful prevention of avian tuberculosis should not be less encouraging than in the mammalian forms of the disease, since the use of tuberculin as a diagnostic agent has become available.

In formulating preventive measures, the facts considered under the heading of modes of transmission should be kept constantly in mind.

The owners of a healthy flock, should be careful in the introduction of new stock and when the latter is procured from unknown or questionable sources, it would be advisable to subject the fowls to a tuberculin test before they are permitted to mingle with the healthy birds.

Offal from fowls dressed for table use should be destroyed by burning and especially so if obtained from outside sources.

We do not know at this time to what extent transmission by such carriers as pigeons and sparrows is to be feared, but efforts should be made to eliminate them, if it is known that poultry flocks close by are affected with tuberculosis.

When the disease has once become introduced into a flock, it is advisable to begin culling out all the old stock, and to kill them for table purposes, their condition permitting. This is not only a very efficient measure in the prevention of tuberculosis, but must be regarded as good poultry husbandry as it is doubtful that birds over two years old pay for themselves unless they constitute especially desirable breeding stock.

As the data, published above showed the older fowls in an affected flock are for the larger portion diseased and as such constitute the most important factor in the distribution of the disease.

After the elimination of the older birds, the remainder of the flock may be tuberculin tested in the manner indicated above and all fowls reacting either typically or doubtfully should share the same fate as the older birds.

In many of the infected birds the lesions will be found to be slight or confined to just one organ. In a few of our reacting chickens it required a long continued search through the organs before the lesion could be discovered. As in the use

of tuberculin in other animals, the reagent, used in chickens merely indicates that tuberculous infection is there and never the extent of the lesions. Fowls in fair condition and with only slight or limited lesions must be considered fit for table use.

Certain phases of the management of poultry must be given consideration in connection with tuberculosis. Clean, airy, well lighted quarters are less apt to promote the spread of the disease than when the opposite is the case. Close crowding of the birds in ill-ventilated quarters especially favors the rapid spread of the disease when one or more infected birds are present. This factor is quite important in this state, where the rather severe winters often compel us to keep our poultry housed for long periods. The writers have frequently observed instances in which the crowding together of fowls during the winter was followed by a very rapid and complete dissemination of the disease.

On this ground it seems advisable to eliminate all old fowls not desired as breeding stock, at the beginning of winter and subject the remainder of the flock to a tuberculin test. At that time of the year, the dressed birds can be usually kept in a frozen condition until required for the table. In this manner, actual losses can be reduced to a minimum.

After the diseased birds have once been disposed of, the quarters and all eating and drinking utensils must be thoroughly cleansed and disinfected. When the diseased birds were kept in enclosed runs, it is also advisable to abandon those for a season.

To what extent the disease is transmitted by means of eggs cannot be said at this time, but even if the danger from this source is probably a slight one, common prudence should cause one to avoid the use of eggs from tuberculous birds for setting purposes.

As an indication of what may be accomplished in the eradication of tuberculosis from a rather heavily infected flock of chickens, the writers may relate the following experience:

In the beginning of 1913 a flock of 249 chickens was found by tuberculin test and autopsy to be tuberculous to the extent of 43.37 per cent. Eliminating all reacting and undesirable birds, fifty-six non-reacting fowls were retained to which were added forty-seven new purchases, which did not react to the test, making a total of one hundred three fowls. During the summer one more bird died with tuberculosis and must be regarded as a case which failed to react on account of very extensive lesions. Some more birds died of other causes (heat, hemorrhages, etc.) before the next test could be made.

The last test was made one year after the previous one. The flock had in the mean time again increased to two hundred forty-nine fowls and the test revealed only 2.41 per cent. of tuberculosis. All those cases showed very slight lesions, probably incipient, and may be attributed to infection by the missed case which died during the summer.

RELATION OF AVIAN TO MAMMALIAN TUBERCULOSIS

In view of the increasing degree of interest now centering around tuberculosis as a factor in public health, as well as in its economic aspects, it seems wise to inquire into the relations of avian tuberculosis to that of mammals, and to review some of the evidence thus far presented.

There can be no doubt that such a relation was suspected even long before the discovery of the tubercle bacillus. Eberlein (84) tells us that Gerlach in 1875 transmitted fowl tuberculosis to three rabbits and two swine by feeding. Straus (261) also found that avian bacilli could produce slight lesions in rabbits but found them apparently less susceptible than guinea pigs. Weber and Bofinger (283) found that rabbits would contract avian tuberculosis and would do so more readily by the ingestion of tuberculous material than by sub-cutaneous inoculation. Koch and Rabinowitsch (146), Bang (11) and Hastings and Halpin (104) found that rabbits are susceptible to avian tuberculosis. Bang (11) and Cobbett (54) report cases of spontaneous infection in rabbits. Moore (183) reports negative results of his infection experiments.

Guinea pigs were found to be liable to avian tuberculosis by Straus (261), Pansini (208), Mursajeff (91), Weber and Bofinger (283), Koch and Rabinowitsch (146), Edwards (86), and Hastings and Halpin (104), while Pernot (214) and Moore (183) on the other hand failed to secure transmission in their experiments.

Rabinowitsch (219) encountered spontaneous avian tuberculosis in the rat, while Koch and Rabinowitsch (146) are inclined to ascribe to this animal, as well as to mice, a not inconsiderable part in the distribution of the disease, at least, in zoological gardens. On the other hand, Shattock and Dudgeon (245) found the white rat to be resistant to the disease, an observation confirmed later by the experiments of Himmelberger (117). De Jong (68) reports spontaneous bird tuberculosis in mice and the same animals are also held to be susceptible by Weber and Bofinger (283).

Steriopulo (253) describes two cases of avian infection in goats. Bang (11) made feeding experiments with bouillon cultures of avian bacilli in goats and kids and saw generalized tuberculosis develop as a result.

The transmission of avian tuberculosis to swine has engaged the attention of several authors. Titze (265) observed slight lesions in the mesenteric and portal lymphnodes of pigs after they were fed with great amounts of avian bacilli. Typical organisms could again be isolated from the lesions. Of three six week old pigs fed with five, ten and fifteen cubic centimeters of avian culture by Bang (11) only the one receiving the smallest amount showed lesions, the other two escaping infection.

Hastings and Halpin (104) fed four hogs on avian tuberculous tissues and all animals showed lesions when slaughtered five or six months later. The lesions were confined to the cervical and mesenteric lymphnodes.

Mohler and Washburn (179), de Jong (72), Rasmussen (226), Christianson (51), and Junack (131) saw the disease occur spontaneously in swine, some of them in the form of regular outbreaks. In the Danish and American cases contact with infected birds could be shown and the investigations made by Bang (13) leave no doubt as to the origin of the disease.

Bouillon cultures of avian bacilli were fed to three calves by Bang (11) and the animals developed marked intestinal tuberculosis with involvement of the mesenteric lymphnodes. The animals died or were killed in a moribund condition in from thirty-nine to sixty-three days. Himmelberger (117) also succeeded apparently in infecting calves with avian material.

A tubercle bacillus corresponding to the avian type was isolated from abdominal lesions of a horse by Nocard (203). Bang (11) included in his feeding experiments two horses and a colt. Both horses, which were fed with large amounts of bouillon cultures representing thirteen avian strains were found to be free from tuberculosis after eight months, while the colt died fifty-five days after consuming one hundred grams of bouillon culture. The autopsy of this colt revealed marked enlargement and beginning caseation of the mesenteric lymphnodes, swelling and small ulcers of the solitary follicles, while microscopic nodules were found in the liver. Titze (265), on the other hand, obtained negative results in a feeding experiment with a colt. Zwick (291) only met with human and bovine strains of bacilli in the six cases of horse tuberculosis, which he examined.

Rabinowitsch (223) found a case of spontaneous tuberculosis in a monkey due to avian infection.

The avian bacillus has been but rarely found to be associated with tuberculosis in man. Pansini (207) expresses the opinion that such infection actually occurs. Nocard (204) and Rabinowitsch (221) encountered avian bacilli in human lesions. According to Löwenstein (158) avian tuberculosis is more common in man than heretofore accepted.

After reviewing the evidence summarized above, it becomes apparent that many strains of avian bacilli are actually pathogenic to mammals, but to a considerable less extent than the organisms associated with spontaneous mammalian disease.

With the possible exception of swine, the danger to mammals from avian infection sources is probably very slight and negligible. We do not know, however, how soon an avian organism in a mammal may become adapted to its new surroundings and become capable of producing mammalian disease with regularity. Such a possibility is indicated by the results obtained by Bang (12) and Cadiot, Gilbert and Roger (42).

In view of this possible source of danger, however slight, it may be, it is apparent that prudence demands, that fowl tuberculosis be so managed as to prevent its transmission to other farm stock.

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**Report of Four Years Work of the North Dakota Holstein
Cattle Breeding Circuit**

By J. H. Shepperd and W. B. Richards

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REPORT OF FOUR YEARS' WORK OF THE NORTH DAKOTA HOLSTEIN CATTLE BREEDING CIRCUIT

INTRODUCTON

The North Dakota Holstein Cattle Breeding Circuit was organized under the plan suggested by a committee of the American Breeders Association which had in charge plans for cooperation in animal breeding. A copy of the report of this committee will be found in the Annual Report, Volume III published by that association for the year 1907. It is a plan advocated by Hon. W. M. Hays and was probably presented to that committee in major part at least by him as one of its members.

The project is designed primarily as a breeding study of dairy cattle. It will enable the investigators in charge of the work to make such blood combinations as will determine which strains and combinations of strains will constitute high producing families. It will bring a sufficient number of cattle of known performance blood lines under the control of these investigators to enable them to draw positive conclusions as to which lines of heredity may be depended upon to bring high producing cattle. It is contemplated that high producing strains as developed will be drawn together to form a foundation for further improvement and study and that accumulating results may thus be obtained.

The plan provides that the work shall be carried out under the joint jurisdiction of the U. S. Dept. of Agriculture and the State Experiment Station, and that each shall bear an equal share of the expense.

The plan further provides that fifteen to twenty farmers be organized into an association for the purpose of cooperating in the breeding of Holstein Friesian cattle.

The following are the more important things required of the farmer or breeder for membership.

(1) Each member shall purchase, care for and breed at least five cows and one bull of the Holstein-Friesian breed of cattle with a degree of excellence satisfactory to those in charge.

(2) That they individually and collectively follow such decisions, rules and regulations as may be made by the Council in charge.

The work of the Circuit is directed by a Council of three men composed of a representative of the U. S. Department of Agriculture, a representative of the North Dakota Experiment Station and the president of the North Dakota Holstein Cattle Breeders' Association. This Association is composed of the members of the Circuit. The

Council is expected to direct the work of the Circuit and to provide all rules and regulations necessary to the conduct of the same.

Geo. M. Rommel, Chief of the Division of Animal Husbandry of the Bureau of Animal Industry, has represented the U. S. Dept of Agriculture, the writers have successively represented the North Dakota Experiment Station and Mr. John Christiansen has represented the Breeding Association, as its president.



Fig. 1. Ten of the 17 charter members of the North Dakota Holstein Breeding Circuit Association. Beginning at the left of rear row: Chas. Klusman, Sr., D. Schwarting, Henry Holle, Robt. Rush, Herman Kroeger. Front row: Wm. Klusman, Wm. Neas, John Christiansen, Fred Michaels, Wm. Tellman.

The plan also provides for the employment of a field superintendent to act as an executive officer of the Council who is required to perform the detail work in connection with the project. Mr. U. J. Downey with headquarters at New Salem, N. D., has acted in this capacity and has done his work in an acceptable manner.

LOCATION AND ENVIRONMENT OF THE CIRCUIT

The North Dakota Holstein Cattle Breeding Circuit Association has its membership confined to farmers located within a radius of twelve miles from New Salem. The reason for confining the membership to this immediate locality is that a large number of desirable members could be secured there. There are many advantages in having the members located near together. It reduces the expense and emphasizes the community breeding plan.

The members accepted are not expert dairymen and do not have the best facilities for carrying on dairy production operations but they

give promise of staying in the business and show a disposition to co-operate. It was not anticipated that anything phenomenal in the way of producing females would early be developed in this Circuit but a good class of cows for the locality and environment was expected.

One benefit that will come from the organization is a center of supply of a good class of pure bred Holstein cattle of a type and family better adapted for our North Dakota conditions than the average pure bred brought into the state from regions differing in climate and environment.

Another reason for confining the membership of the Circuit to the vicinity of New Salem is the permanency dairying has acquired in that locality. The farmers have been dairying in that vicinity longer, and have made a greater success of the business than has been the case in any other portion of the state.



Fig. 2. Group of those in charge of 12 of the 14 farms represented in the Breeding Circuit summer of 1912. Since the Circuit was organized in 1909 ten of the original members have retired and one or two of the sons have succeeded their fathers in the management of the farm in each instance.

The work has progressed well to date considering the geographic location of the community in which the work is carried on and the general conditions surrounding it. To appreciate the work accomplished, one must become familiar with the New Salem region, its agricultural conditions and the character of the farmers who are members of the Circuit.

New Salem, Morton County, North Dakota, lies west of the 101 meridian and north of the 45 parallel. The region has a limited rain-

fall and the conditions are not the best for crop production. The soil is a clay loam with a clay subsoil capable of giving good yields when supplied with sufficient moisture and the topography is generally rolling and treeless. In some of the area covered by the Circuit, considerable rough land suitable only for grazing is found. Both running and well water of good quality are found throughout the Circuit.



Fig. 3. Farmstead of Herman Kroeger & Sons. Members of the Breeding Circuit. The thrifty and homelike appearance of the farmstead members is one of their notable features.

This district was first settled in 1883 by Germans with little farm experience to guide them, who found it difficult to make much headway raising grain. They did not have sufficient funds to make a start in raising live stock. They finally succeeded, however, in ac-

quiring some cows and began to make butter. This they found to be the surest way of gaining a livelihood for the reason that they always succeeded in getting enough grass for both pasture and hay purposes, if not on their own land, then on the free land adjoining or near at hand.

They found it possible (as their knowledge of the kind of crops to grow increased) to produce considerable winter feed. The native pastures are still depended upon largely for summer feed and wild hay to a considerable extent for roughage in winter. During recent years, they have been successful in growing corn for forage and silos are being erected to preserve it.

These dairymen continue to grow some wheat and other grains for market but do not place heavy dependence upon grain growing as a source of revenue.

In order to show the cropping system employed by the members of the Circuit and the feeds grown the table on page 158 has been prepared.

It will be seen from this table that great dependence is placed upon the native grass for pasture and hay. Considerable dependence is also placed upon prairie hay for winter roughage. The acreage devoted to millet and corn, however, is being increased from year to year.

None of the tame grasses have been grown to any considerable extent by these farmers. Most of the members report successive trials with them and poor results. Alfalfa has, however, made a good showing. This crop they have begun to grow in a small way during the last few years. Alfalfa will probably become their chief hay crop in the future and possibly it will be used for pasture purposes as well. A suitable pasture grass is a great need in this section of the country.



Fig. 4. The herd of Kroeger Bros. under inspection during one of the annual summer picnics held by the members of the Breeding Circuit.

From the table given above it will be seen that approximately 10 acres of land is devoted to each animal kept including young stock. The fact that these farmers who have each devoted from two to twenty-one years to dairying in this community adhere to the native

pasture for summer feed for their cows indicates to the writers that they still find the tame grasses uncertain. However, it may be that they use the native pasture because of the large amount of land which they own and the ease with which they can rent pasture land.

They established creameries in the early stage of their experience in dairying which enabled them to get the most out of their milk. Through Mr. R. F. Flint's efforts as their buttermaker New Salem creamery butter early acquired an enviable reputation for quality which it still maintains. The reputation of this creamery also aided other creameries built in this locality to acquire similar reputations.

The building of the New Salem creamery was followed by the erection of one at Youngtown in 1899, five years after the establishment of the one at New Salem. This creamery was also very successful from the beginning. Its success has been due to a large extent to the effort of D. M. Young the buttermaker in charge there for several years. It is also due to his efforts that some of its patrons as well as some of those at New Salem were induced to invest in pure bred Holstein cattle which in turn aided greatly in establishing the Breeding Circuit. Twelve bulls and about twenty females representing some of the best families, were included in this shipment. They were purchased in Wisconsin during the summer of 1905. These cattle formed the nucleus for Circuit work. The Youngtown creamery received milk exclusively, at least until a very recent date. It is located 9 miles northeast of New Salem and it is one of the most successful creameries in the state. It paid its patrons during the year 1908, \$32,821.58 and for 1909, \$30,412.44. The majority of the members of the Holstein Breeding Circuit deliver their milk to the Youngtown creamery and the balance to the New Salem and Rosebud creameries.



Fig. 5. The farmstead of D. Schwarting, a member of the Breeding Circuit, with the herd in the foreground.

After the two creameries mentioned were established, several other successful ones were located in Morton and Oliver counties. The following quotation from a paper read by John Christiansen, New Salem, President of the North Dakota Holstein Breeding Circuit, before a meeting of the North Dakota Live Stock Association in 1908 shows the hard conditions which these German settlers passed through:

"In the spring of 1883, the first week in April, the advance guard of a colony of German settlers from Wisconsin, Indiana and Illinois, mostly from around Chicago, landed in Morton County, west of the Missouri River, and located on the prairie on the main line of the Northern Pacific railroad, at that time incomplete, at what is now the village of New Salem, (the writer being one of the very first ones and has been here ever since.) After taking homestead and erecting shelter of the most humble kind for the people and some kind of sheds, mostly dugouts, and sod barns for what little stock and horses the settlers brought along, the question, what shall we do now to make a living in this new and untried country, became serious. From the experience of others, we could not learn anything, for there was nobody here trying to make a living from farming when we arrived. The prospect looked blue, sure, although we were shown a few ears of corn at Mandan, said to be raised near there, but hardly any broken prairie was visible. We were told in the East of the fortunes made in Dakota Territory by raising wheat and that we could get rich quick by raising wheat and then we could go back East and live in fine style. So, accordingly, we went to work and broke up the prairie, very slowly, of course for want of power to pull the plow, but some breaking was done, grain put in, mostly wheat and oats, and as the work was naturally done poor and the seasons of the late eighties were dry, very little harvests were gathered for years. These conditions took the courage out of a great many of the settlers and some even went away after borrowing all they could on their land (\$300 to \$400 was all anyone could get on a quarter section) and left their farms for other fields. A number of us stayed and as fast as we could get a hold of some cows that could be milked, made butter from the milk at home and traded it in the New Salem stores for the most needed things for the house and family. Cash was never paid in those days for butter and the trade unsatisfactory to both parties. Chickens were also kept a good deal and eggs traded in the same way."

"Thus the first years of the settlement passed not always in plenty, and something had to be done, or tried for a more certain income. Feed, that is, natural pasture and prairie hay, was generally plenty and of good quality, live stock, cattle, horses and sheep had to come to our salvation. The establishment of a creamery was thought of by some of the farmers, who came from the neighborhood of Elgin, Ill., to be the only thing that was certain of success if milk enough could be produced. Before any action was taken, however, W. H. Mann, one of New Salem's old settlers and business men, with a view of improving the grade of butter, started a one horse power creamery in the basement of his dwelling and sent a team out into the country every day to gather cream that was mostly raised in long narrow cans kept in water. This was some improvement to making butter at home, but too expensive to run, as not enough cream could be had. Results

for the farmer were not very satisfactory, either as no test of any kind was used. The good cream was not better paid for than the poorest and the first creamery did not run very long, but had done enough to show that cash could be gotten out of the butter. Then a movement was made to get a model creamery started in New Salem in 1894. The business men agreed to put up the building, put in the machinery, make the butter, ship the same furnishing everything for four cents per pound for butter providing a number of farmers would agree to bring all the rock needed gratis and bring all the milk they had. This was agreed to and work was begun at once and the now famous New Salem creamery built, the first one in the state where only whole milk was delivered and let me tell you right here, it has been running successfully ever since, winter and summer and has been a great benefactor both to the farmers and business man. A trip through the country will prove this by the good, substantial buildings, both houses and barns and the herd of contented, well cared for cattle than can be seen on every farm from which milk is delivered to the creameries.

After the success of this creamery was evident it was only natural that new ones were established and at present there are seven creameries shipping their products from New Salem."

TIME AND DETAIL OF ORGANIZATION

The North Dakota Holstein Cattle Breeding Circuit was organized during the year 1908 and 1909 after frequent visits by W. B. Richards to New Salem. The members organized themselves into an association during the winter of 1909 and elected their officers.

The following farmers constitute the charter members:

John Christiansen & Sons.....	New Salem
Wm. Neas.....	New Salem
Herman Kroeger	Youngtown
Herman Benker	Youngtown
Henry Holle	Youngtown
D. Schwarting	Youngtown
Wm. Tellman	Rosebud
Wm. Klusmann	Youngtown
Fred Michaels	Youngtown
Chas. Klusman, Sr.	Youngtown
Robt. Rusch	Rosebud
Moritz Tausand	New Salem
Carl Holle	New Salem
Frank Gaebe	New Salem
John Schultz	Glen Ullin
O. Brown	Dickinson

The two last named members were not retained since they were not located within easy reach of the other members. All of the other

members have been retained with the exception of Herman Benker who was dropped from the list because of non-conformity to the rules of the Circuit. In many cases the farms of the charter members have been taken over by the sons, as several of the fathers have retired since the Circuit was organized. This will explain the changes in names which appear.



Fig. 6. One of the Holstein sires as a two year old in use in the Circuit.

Several of the members had some pure bred Holstein cattle before the Circuit was established, obtained from the shipment made by D. M. Young already mentioned. These cattle were accepted as a part of their required allotment.

During May of 1909 a carload of females was purchased in Wisconsin to supply those who had no pure breeds and to add to the number owned by the other members at the time of organization. No member owned more than 5 pure bred females when the work began; some started with only one, others had two, and so on. They all, however, owned pure bred bulls which were brought in with the original shipment before the Circuit was organized or were secured from the increase from that shipment. It will be seen that an exception was made to the plan by accepting members with less than five females, Conditions seemed to justify doing so.



Fig. 6½. Farmstead of John Christiansen.

Each member had 15 to 20 native or grade cows in addition to the pure bred ones. They have been allowed to use the pure bred Holstein bulls upon these native and grade cows. This has resulted in the production of a large number of half and three-quarter blood females to date, which are being used to replace the native cows. These grades will be retained until they are replaced by pure breeds from the increase. The grade Holsteins in the herds have been a strong object lesson in convincing the members of the value of good blood. The surplus grade heifers that could be spared have been sought for by the farmers of the immediate locality and some have been purchased by buyers from the extreme western part of the state.

Records have been kept of the production of the native and grade cows in the herds as well as of the pure breeds. This has enabled intelligent culling of the natives and grades, and has proven a means of comparing the relative value of the natives and grades with the pure breeds.

HOW THE WORK IS CARRIED ON

August first, 1909 record keeping work in the Circuit was begun. At that time a field superintendent was stationed at New Salem, and put in charge. The first thing done was to test all the cows owned by members of the Circuit for tuberculosis. Fortunately only 3 or 4 positive reactions were found in herds retained in the Circuit. Two of the reactors were pure bred cattle which had been shipped into the herds. The results substantiate the claim that cattle under natural conditions are generally free from the disease unless it is introduced by infected cattle.

On January 1st, 1910 a record of the production of each cow in the Circuit was begun. This was accomplished in the following manner: The members were provided with milk record sheets and scales and required to weigh and to record the weight of the milk produced by each cow at every milking.

The field superintendent visits each herd once a month and tests a sample of the night and morning milk of each cow for butter fat. This test is used as the average for the month in determining the total fat produced. The method employed is similar to that used by Cow Testing Associations and breed Associations in making semi-official tests. The pure bred heifers and cows are tested for the Advanced Registry when their production seems to warrant it. They will also be tested for the yearly semi-official records. This is done without additional expense to the members in so far as it is possible for the field superintendent to act as an inspector by authority of the North Dakota Experiment Station which institution is in charge of the official testing in North Dakota.

RESULTS SECURED

The profits as shown in these records are an approximation. The feed was not weighed at each feeding period but was weighed from time to time for the purpose of obtaining the basis for making an estimate. The figure covering the cost, however, will be helpful as a guide in determining the price at which butter fat can be produced under Western North Dakota conditions



Fig. 7. One of the herds in the Circuit with one of pure bred Holstein cows of good type in the foreground.

The value of the feed consumed by the cows was determined from the average farm prices of the feeds for the time covered by these records. The schedule of prices used is as follows:

SCHEDULE OF PRICES

Pasture @ \$1.00 per mo. per head	
Millet and cereal hay.....	\$ 6.00 per ton.
Corn stover	8.00 " "
Prairie hay	8.00 " "
Bran	22.00 " "
Oats	22.00 " "
Silage	3.00 " "
Straw	free

The tables on pages 115 to 156 give the production of the cows in each herd in the Circuit, the approximate cost of the feed consumed and the net profit or loss made by each cow for the calendar years 1910, 1911, 1912 and 1913.

The tables show that the concentrates fed by all the members did not include more of a variety than three feeds; viz. barley, oats and bran. It may also be noted that bran was fed by only three members during the winter of 1910, while several fed no bran during the winter of 1911. The roughage fed, consisted of prairie hay,

corn stover, flax, straw, cereal hay, millet hay and some silage in a few instances. It will be recalled from the discussion which preceded, that the native prairie is used almost exclusively for pasture purposes and that no soiling crops are fed. Considering the prominent place prairie grass and prairie hay have occupied in the rations of these cows, the results produced must be accredited largely to native prairie products and while the yields are only moderate they indicate a high feeding value for both the hay and pasture. It is poor policy for the circuit members to rely wholly on pasture for roughage during the summer months. The high price of labor and a disposition to continue their methods are the principal reasons for their persisting in their reliance on native forage plants.



Fig. 8. Farmstead of Chas. Klusman, Sr. A new modernly equipped dairy barn has been erected on the farm since this view was taken, a cut of which is shown on another page.



Fig. 9. Another one of the Holstein bulls in use in the Circuit as a two year old.

Taking into account the manner in which the cows in these herds were fed, the yearly records made by some of them are remarkably good. Most of the pure bred cows and the ones that made the more creditable records were fed considerably heavier grain rations than were the average cows of the herd. The rations fed the best producing cows in the Circuit were much lighter and poorer balanced than those commonly fed by good dairymen.

The highest record made during 1910 by an aged cow is credited to Countess Elgin Belle Pet 75,254 owned by Kroeger Bros. consisting of 548.01 lbs. of butter. The best record made by a first calf heifer in her 2 year old form was that of Beryle Lilith Pietertje 112,390 owned by Wm. Neas.



Fig. 10. Farmstead of Henry Holle. Note the silo. Six other members were induced to erect silos since the Circuit was organized.

For the year 1911 Countess Elgin Belle Pet 75,254 again headed the list as the highest producer for an aged cow making 462.7 lbs. of butter. She was closely followed for second place by Beryle Lilith Pietertje owned by Wm. Neas with a record of 409.9 pounds of butter.

Skylark Ormsby Hengerveld DeKol owned by Diet Schwarting produced the largest amount of butter for an aged cow during 1912, consisting of 357.1 pounds. Dakota of Elmwood owned by Chas. Klusman, Sr. led the two year olds for 1912 with a butter record of 371.1 pounds defeating all other aged cows for the year.

In 1912 Ladi Rense Surprise a six year old cow in the herd of Frank Gaebe was the ranking cow with 333.8 pounds of butter fat while Dakota Jeanette Kaan owned by Kroeger Bros. led the two year old cows of the Circuit with a record of 265.8 pounds of butter fat.

It should be remembered that all these records are for the calendar year and not for the lactation period. For this reason, they do not express the maximum yearly records of the cows. The records quoted above, it will be seen, by referring to the tabular statements show that they did not milk the full 365 days as is generally the case when their records are calculated for the calendar year.

The low records of production shown by some of the cows in the herds were due to the short time they were in milk during the year. In many cases care was not taken to breed the cows so as to avoid their being dry for a long period.



Fig. 11. One of the herds in the Circuit contentedly grazing on the natural prairie pasture.

Reference to the tables appearing on pages 115 to 154 will indicate that many of the cows classed as natives made good records. Most of these cows were exceptionally good individuals. The farmers of the Circuit had practiced careful culling of their herds for some years before the Circuit was instituted which accounts for the finding of natives with good performance records. The fact that nearly all these native cows were at the age of maximum production must also be kept in mind in comparing their records with those of the pure bred and grades, since most of the pure bred and grades were heifers and young cows.

INTERPRETATION OF THE RECORDS GIVEN IN TABULAR FORM.

These tables give the records of individual cows for the years 1910, 1911, 1912 and 1913.

The chief reason for publishing a statement at this time is to place the records given in the appended tables in permanent and available form.

The historical statement relative to the Circuit was made for the purpose of acquainting the reader with the conditions under which these records were made. Sufficient time has not elapsed since the Circuit was organized to formulate a report of much value on the problem of breeding, except in a casual way.

The environment, skill of the members, geographic location and the feeds grown and fed must be kept in mind to fully appreciate the records made by the cows in this Circuit. The records made by the pure bred cows in the circuit herds and by the natives would indicate that they must be good cows of their class considering the manner in which they were fed. Tables have been compiled showing the average amount and kind of grain and roughage fed as a daily ration to the mature cows in the herds during the months of January of 1910 and 1911 which are typical of the rations fed throughout each winter of the four years covered by these records. A study of these tables which

appear in the appendix, will show that the grain ration fed was extremely light and not composed of the best milk producing concentrates; that clover and alfalfa were not fed and that silage was used in only a few of the herds during 1911 and 1912.

A COMPARISON OF THE RECORDS OF PRODUCTION FOR THE FOUR YEARS

Table LXI gives a comparison by years of the average production of all the herds. These tabular statements give a measure of results accomplished by each member of the Circuit for the four years and show whether their herds average higher in production as the years pass.

The cows of the entire Circuit produced the following average amounts of butter per head at the profit per cow noted:—

	Average butter produced.	Profit per cow
	Lbs.	Dollars
In 1910	210.2	30.83
In 1911	223.9	24.31
In 1912	214.3	32.34
In 1913	248.3	33.62

From the above statement it will be noted that the cows have made an increase in the yield of butter per head during the four years covered in this report with the exception of the year 1912. In 1912 a large proportionate number of young cows in their first period of lactation were included in the Circuit which accounts for the lower average yield for that year. The income per cow per year is governed in part by the yield of butter and in part by the price received on the market. For this reason the year 1911 is the low one in point of money earned per cow. The average price received for butter at the New Salem and Youngtown creameries in 1910 was thirty-one cents and in 1911, twenty-three and a half cents per pound.

Just previous to 1912 and during that year, many native cows were replaced in the herds with first calf heifers. Tables LXI shows that the cows used in the Circuit average younger in 1912 than they did during the previous two years. The members of the Circuit fed their cows better during 1912 than during 1910 and 1911, but many of the cows did not yield as well as they did during the previous two years. The lack of good feeding, especially during the summer of 1910 and 1911, which were extremely dry short pasture seasons reacted on the production of the cows during the year 1912. This as well as the difference in the ages of the cows probably accounts for the reduction in the yields for 1912.

COW PLACED IN THE ADVANCED REGISTRY

An effort has been made to test as many of the heifers in the Circuit as possible for the Advanced Registry. In table LXII will be found a list of the heifers which were tested for the Advanced Registry prior to August 1st, 1913. The tabular statement gives their breeding, their records, etc. It will be noted that the records made are not large. Most of the heifers would have done better if they had been given good care and larger and better balanced rations during the test period. Up to date those in charge have been unable to get the Circuit members to appreciate the necessity of preparing their heifers before calving and of feeding them liberal and balanced rations while under test.

Too few heifers have thus far been tested to indicate that any one bull is proving better than another as a sire of high producing females.

THE HERD BULL IN USE

Table LXIII includes a list of the herd bulls used in the Circuit during the year 1913. An investigation of the breeding of these bulls indicates that they have what is called fairly good breeding. They have been selected more on the basis of their performance than upon their breeding. The aim has been to combine merit and breeding in the selection of the bulls, in so far as the money available would warrant. Those in charge have been unable to get the cooperating farmers to invest to exceed \$200 in a bull. This has placed considerable restriction from the standpoint of breeding upon the results that might be accomplished. A failure to get members to conform to all the requirements may be noted as one of the difficulties in the work of a cooperative live stock breeding circuit.



Fig. 12. A group of one half and three quarter blood heifer calves on the farm of one of the members. Note most of them show characteristics Holstein markings.



Fig. 13. A modern equipped dairy barn nearing the stage of completion on the farm of Chas. Klusman, Sr. being inspected by the members of the New Salem Commercial Club under the direction of field superintendent U. J. Downey. The management of the Circuit assisted the owner in planning this barn.



Fig. 14. A Holstein bull calf of serviceable age ready for the market.

Some of the bulls used have proved to be very much better sires than others. The older bulls in use at the present time have been retained because they have shown special merit. It has not been possible to keep some promising bulls in the Circuit because they were vicious and the members objected to handling them. To get the bulls properly handled and cared for is one of the greatest difficulties to be surmounted.

THE SALE OF SURPLUS STOCK

The demand for the surplus pure bred Holstein cattle which have been raised in the Circuit as well as for the grades has been marked. No pure bred Holstein heifers have been sold outside of the Circuit, as they have all been needed to replace the natives and grades in the herds of the members. The pure bred Holstein bulls which have not been needed in the Circuit have been readily sold each year. The Circuit has had 20 to 25 bulls to dispose of annually and they have brought \$100 to \$150 apiece when six to eighteen months old. Most of the sales have been made through the officers of the Circuit or by the Field Superintendent. The fact that the Federal and State authorities are helping to direct the work of the Circuit gives the public confidence in the merit and reliability of what is offered for sale from the Circuit. Many of the bulls have been taken by farmers in the immediate vicinity of the breeding circuit. The bulls sold outside of the Circuit have been shipped to widely scattered points in the state.

There has been a keen demand for the surplus grade heifers and cows which have sold at remunerative prices. The demand has far exceeded the supply for this class of stock in this state during the past few years. The prices which the buyers have been willing to pay make the raising of good grade dairy cows a profitable business.



Fig. 15. Scene at the Annual Summer Picnic of the Breeding Circuit 1912. These picnics and other meetings held under the auspices of the Circuit have done much to educate the members and to promote cooperation and interest in the work of the Circuit and in dairying.

ASSISTING THE MEMBERS

Every effort possible has been made to assist the members of the Circuit to obtain better results with their herds. The Field Superin-

tendent is available at all times to furnish them with information regarding the care and management of their cattle. Two meetings have been held each year for the purpose of educating and arousing interest in the members along the line of better dairy methods and practices. The best speakers obtainable in the state have appeared on the program of these meetings. A club has been organized, composed largely of Circuit members which has held meetings once a month. The club members discuss questions relating to the raising and feeding of dairy cattle.

Five of the members of the Circuit erected silos in 1911. These were the first silos built in the community. Other silos are being erected as a result of this demonstration. Those who have built silos are well satisfied with the results obtained.

During the summer of 1913 several of the members were induced to erect new barns or to remodel their old ones and equip them with cement floors and sanitary stalls.

The members are assisted in the registration of their pure bred cattle and find it a great advantage to have a market thus supplied. They also appreciate the fact that sales are made much more readily where a large number are keeping the same breed of stock as is the case in this community.

DIFFICULTIES MET WITH

While the results secured in the circuit have been commensurate to the money expended in the work, they have not been as great as one might expect from the plan under which the work is organized. In any cooperative work the type and magnitude of the results obtained depend largely upon the material one has to work with.

With the class of housing and feeding which the hard owners of the Circuit have practiced it is impossible to obtain high class milking records no matter what blood lines are used nor what types of cows the herds contain. A lack of capital on the part of the members is an item which must be taken into consideration.

Difficulties arise that might be met with in any cooperative organization. There is a tendency on the part of the farmers to resent being dictated to concerning the care and disposition of their stock. It is in some cases hard to get them to follow instructions. It was with considerable difficulty that they were induced to buy the bulls recommended although those selected were within the range of prices which they were willing to pay. Some trouble was experienced in getting them to dispose of undesirable bulls. Aside from these the chief difficulty has been to get the members to appreciate the value of good care and to give their cattle the attention required for best results. The shortcomings encountered in this respect can readily be seen from the discussion in the preceding pages.

TABLE I. HERD OF HERMAN BENKER. RECORD OF PRODUCTION FOR YEAR 1910.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat		Total Cost of Feed		Profits	
								dols.	dols.	dols.	dols.	dols.	dols.
Slicky	6	Native	334	6594.4	3.94	260.0	304.0	88.12	38.69	49.43			
No. 2	6	Native	304	6878.7	4.22	289.4	387.5	101.24	41.44	59.80			
Rosie	8	Native	275	5654.8	3.76	212.7	248.5	71.76	34.50	37.22			
Bloody	7	Native	294	6389.7	4.46	285.4	332.8	99.06	37.50	61.56			
No. 5	3	1-2 B.Hol	317	4564.5	4.21	192.2	224.3	66.87	32.18	34.69			
Lizzie	4	Native	335	4059.9	4.00	162.1	189.1	55.05	31.46	23.59			
Trassie	6	Native	314	5821.1	4.14	241.4	281.4	84.39	36.42	47.97			
Mollie	8	Native	272	5931.3	4.31	256.7	299.4	89.78	38.29	51.49			
Daisy	5	Native	284	5237.0	4.11	216.5	252.6	75.05	35.58	39.47			
Black Kicker	12	Native	234	4831.0	3.80	187.4	218.6	68.19	36.53	29.66			
Stella Max de Kol	2	P. Br.	245	4237.0	3.90	166.0	193.6	54.69	35.87	18.82			
Lily	8	Native	314	4140.2	3.50	145.1	169.3	50.20	33.62	16.58			
Fanny	5	Native	304	5456.3	3.92	214.2	249.8	70.92	33.00	38.02			
Grata	7	Native	274	3813.0	4.17	169.1	197.5	56.34	31.64	24.70			
Paika	8	Native	255	3656.1	4.42	163.3	190.5	52.41	31.02	21.39			
Spitz	7	Native	226	2721.6	2.70	114.6	133.4	36.55	28.26	7.29			
Short-teat	10	Native	265	4305.8	4.30	186.5	217.3	52.55	30.28	22.27			
Fanny	10	Native	225	4849.0	4.30	210.7	245.5	69.34	31.90	37.44			
Jennie	8	Native	296	4649.6	4.51	210.0	245.0	69.46	30.28	39.16			
Mary	3	1-2 B.Hol	304	3953.3	3.90	154.0	179.6	51.09	33.00	18.09			
Manda	3	1-2 B.Hol	280	2909.2	4.33	127.5	148.5	42.26	28.22	14.04			
Kate	3	1-2 B.Hol	275	3549.2	4.10	147.8	172.5	48.45	30.98	17.47			
Average of all cows	6.3		283	4740.0	4.04	195.9	228.6	65.98	33.66	32.28			

TABLE II.—HERD OF JOHN CHRISTIANSEN & SON. RECORD OF PRODUCTION FOR YEAR 1910.

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Ann.....	7	Native	334	3389.5	4.00	135.2	157.7	46.00	27.08	18.92
Beauty.....	2	Native	365	5524.7	3.37	197.5	230.0	68.68	28.94	39.74
Belle.....	4	P. B. Hol	385	5680.8	3.75	213.0	248.5	70.69	27.86	42.73
Alice.....	7	P. B. Hol	304	7964.2	3.41	273.7	319.2	95.09	33.72	61.37
Gem.....	7	P. B. Hol	335	6341.7	3.46	215.0	249.6	71.37	30.67	40.70
Bessie.....	2	Native	307	4804.5	3.62	174.0	203.0	58.79	28.00	30.79
Maggie.....	2	Native	334	4076.1	3.25	132.7	155.0	43.04	26.35	16.69
Blossom.....		Native	373	5102.0	3.49	178.1	207.7	63.68	31.30	32.38
Red Star.....		Native	304	4849.6	3.88	189.2	220.6	61.91	26.30	35.61
Queen.....	9	Native	245	4852.8	4.20	205.4	239.5	65.64	28.08	39.56
Daisy.....	9	Native	274	4446.1	3.50	155.8	181.9	52.85	26.76	24.09
Lottie.....	8	Native	334	5152.4	4.17	260.0	291.7	83.66	27.06	56.60
Jessie.....	10	Native	304	5267.0	3.47	183.0	213.5	61.20	27.57	33.63
Bedney.....	12	Native	273	2851.3	3.58	111.9	130.5	39.68	23.76	15.92
Flory.....	7	Native	304	4076.5	3.89	158.6	184.7	55.58	27.50	28.08
Average of all cows.....	6.6		315	4958.6	3.66	184.8	215.5	62.51	28.06	

TABLE III.—HERD OF FRANK GAEBE, RECORD OF PRODUCTION FOR YEAR 1910.

Sarah.....	6	Native	334	4747.2	3.97	188.4	219.8	63.25	27.67	35.58
Daisy.....	3	B. Hol	255	1980.7	4.16	82.5	95.2	26.24	26.05	19
Redy.....	8	Native	268	3654.5	4.44	163.6	190.8	55.04	29.35	25.69
Brownney.....	5	Native	269	3910.3	4.17	153.3	178.8	54.77	30.01	24.76
Bloome.....	7	Native	304	6001.9	3.66	219.8	256.4	77.39	33.95	43.44
Whitie.....	9	Native	304	4765.1	4.26	203.1	236.9	71.37	32.73	38.64
Princess.....	9	Native	304	4558.4	4.17	190.0	221.6	65.93	31.37	34.56

Spottie	4	B.Hol	365	4387.6	3.60	158.2	184.5	54.44	28.47	25.97
Buntie	5	Native	304	2817.2	4.31	121.4	141.6	42.21	28.03	14.18
Nancy	6	Native	304	2097.0	4.35	91.0	106.1	28.08	26.71	1.37
Bess	4	B.Hol	245	1672.1	3.83	64.2	74.9	19.90	23.25	3.35*
Star	4	B.Hol	275	2419.6	3.80	91.2	106.4	28.43	23.95	4.58
Mary	4	B.Hol	275	2508.4	3.59	90.0	105.0	28.42	23.95	4.57
Queen	4	B.Hol	304	2993.5	3.43	102.8	119.9	33.62	25.31	8.31
Nettie	14	Native	214	2506.3	3.30	82.6	96.3	24.97	23.25	1.72
Babe	7	Native	275	2981.7	3.80	111.9	130.5	35.60	24.61	10.99
Cowboy	7	Native	275	4015.9	3.20	129.7	151.3	40.81	24.61	16.20
Average of all cows	6.2		286	3412.7	3.88	131.9	153.8	44.14	27.25	16.90
* Loss.										

TABLE IV.—HERD OF GEORGE HOLLE, RECORD OF PRODUCTION FOR YEAR 1910.

No. 2 Daisy Ormsby	6	PB Hol	322	10692.5	3.41	364.8	425.6	122.33	38.90	83.48
Koan Jewel Canary Merchant	6	PB Hol	337	8437.2	4.32	300.1	351.1	95.28	34.10	61.18
Average of all cows	6.0		329	9564.8	3.86	332.4	388.3	108.80	36.50	72.30

TABLE V.—HERD OF HENRY HOLLE. RECORD OF PRODUCTION FOR YEAR 1910.

Minnie	4	1-2 B.Hol	244	3397.5	3.70	125.7	146.6	39.43	26.36	13.07
Lizzie	6	Native	263	6184.5	3.70	228.7	266.8	74.56	28.44	46.12
Blossie	5	Native	319	4227.2	4.00	169.3	197.5	66.68	26.42	30.26
Fannie	3	1-2 B.Hol	273	4672.1	3.30	154.4	180.1	61.51	30.46	31.05
Spottie	8	Native	315	6609.7	3.80	250.8	292.6	86.09	32.52	53.57
Lily	3	1-2 B.Hol	235	4709.3	3.59	168.6	196.7	59.78	31.16	28.62
Nellie	7	Native	263	4684.2	3.91	183.3	213.8	61.80	28.44	33.36
Batsie	8	Native	300	5576.5	3.85	204.8	238.9	79.99	33.22	46.77
Boesie	9	Native	195	2969.7	4.37	126.6	147.7	43.31	26.42	16.89
White Face	7	Native	304	5170.7	3.90	201.5	235.0	69.76	30.46	39.30
Blackie	4	1-2 B.Hol	261	5472.9	3.70	203.1	236.9	70.15	33.22	36.93
Kaan Maries of Edgetown	7	PB Hol	282	9399.1	3.20	304.6	355.3	107.16	33.94	73.22
Daisy	4	1-2 B.Hol	270	4334.7	3.51	152.3	177.7	49.04	27.08	21.96
Dora	4	1-2 B.Hol	306	4385.7	3.40	150.2	175.2	49.08	27.74	21.84
N. Star Bess	3	PB Hol	260	3715.7	3.40	129.1	150.6	41.44	27.04	14.40

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Slickie	2	1-2 B.Hol	159	3990.5	3.70	150.6	175.7	51.10	15.30	35.80
Jersey	5	Native	244	3870.3	3.70	144.9	169.0	46.18	27.08	19.10
Long Neck	8	Native	304	5188.5	3.60	187.1	218.3	61.33	28.44	32.89
Tressie	2	1-2 B.Hol	273	4682.8	3.90	181.5	211.7	59.86	28.44	31.42
Spitz	7	Native	335	5079.0	3.98	201.6	235.2	67.11	29.10	38.01
Flossie	5	Native	269	4507.6	3.90	177.5	207.0	57.39	27.08	30.31
Average of all cows	5.2		270	4895.1	3.71	180.7	210.8	61.55	28.49	33.06

TABLE VI.—HERD OF CHAS. KLUSMANN, RECORD OF PRODUCTION FOR YEAR 1910.

No. 1	12	Native	365	6198.7	4.47	227.9	265.8	76.69	29.71	47.08
No. 2	2	1-2 B.Hol	286	3891.0	3.87	140.4	163.8	47.73	27.78	19.85
No. 5 Alma Marie 6th Daughter	2	P B Hol	304	5379.4	3.86	213.0	248.5	70.18	28.42	41.76
No. 4	8	Native	329	5276.9	3.64	192.2	224.2	63.86	29.41	34.45
No. 6	6	1-2 B.Hol	333	5744.5	3.66	210.5	245.5	70.94	26.92	44.02
No. 7	7	Native	245	3766.0	3.90	146.9	161.4	47.12	24.82	22.30
No. 11	2	1-2 B.Hol	304	4509.1	3.78	148.5	172.9	51.04	25.48	21.82
No. 21	8	Native	289	4073.0	3.68	150.0	175.0	49.28	27.46	20.34
No. 22	2	1-2 B.Hol	245	2514.9	4.01	100.8	117.6	32.91	23.62	9.29
Average of all cows	5.4		300	4593.7	3.87	170.0	197.1	56.63	27.06	28.99

TABLE VII.—HERD OF JOHN KLUSMAN, RECORD OF PRODUCTION FOR YEAR 1910.

Blackie	7	Native	304	4924.3	3.36	165.4	192.9	55.81	27.80	28.01
Brownie	7	Native	273	5011.3	4.12	206.7	241.1	67.43	27.32	40.11
Baby Babus Snowflake	6	PB Hol	253	5548.7	3.12	173.4	202.3	61.24	31.27	29.97
Bobtail	8	Native	250	4867.3	3.96	192.8	224.9	63.87	27.61	36.26

Bessie	3	1-2 B.Hol	385	3886.3	3.93	182.9	175.	51.60	26.66	24.95
Gusta	10	Native	365	5760.0	4.03	232.5	271.2	77.83	28.60	49.23
Jersey	8	G.Jers	324	5656.5	4.00	223.8	257.7	78.62	28.83	49.79
Lillie	9	Native	304	5066.7	4.05	205.4	239.6	69.84	27.72	41.62
Moonlight	10	Native	298	3794.4	4.64	172.4	201.1	57.64	23.40	34.14
Marble	8	Native	298	5043.9	4.07	205.7	240.0	69.56	28.83	40.73
Nellie	11	Native	214	3321.3	3.64	121.0	141.1	38.79	24.15	14.64
Scrub	8	G.Her	324	6043.0	4.00	242.0	282.2	83.21	32.63	50.68
Star	7	Native	304	5502.3	4.17	229.7	268.0	79.53	32.60	46.93
Short-horn	7	Native	269	4634.0	3.91	182.1	212.4	61.94	30.36	31.58
Tillie	3	1-2 B.Hol	289	4326.7	3.87	168.6	196.7	59.04	27.50	31.54
White Face	8	Native	268	4731.3	3.91	187.0	218.1	61.07	30.92	30.15
Bird	2	1-2 B.Hol	290	2801.0	4.00	112.7	131.5	36.75	26.43	11.32
Pet	2	1-2 B.Hol	269	2930.7	3.91	114.6	133.7	37.38	26.08	11.30
Average of all cows	6.8		291	4655.4	3.92	182.7	212.7	61.69	28.26	33.43

TABLE VIII.—HERD OF KROEGER BROS. RECORD OF PRODUCTION FOR THE YEAR 1910.

No. 1	8	Native	274	4135.7	4.16	172.0	200.6	59.62	26.36	33.26
Pietertje De Kol Mechthilde	5	PB Hol	334	9261.8	3.40	315.3	367.8	105.63	38.09	67.64
Junette Madrigal	6	PB Hol	344	9255.6	3.89	342.8	400.0	119.21	39.50	79.71
Countess Elgin Belle Pet.	6	PB Hol	365	12100.3	3.88	469.7	548.0	159.91	49.74	110.17
No. 5	2	1-2 B.Hol	304	4067.1	3.55	144.5	168.6	51.01	22.42	28.69
No. 6	2	1-2 B.Hol	319	4847.0	3.81	184.7	215.5	60.92	23.72	37.20
No. 8	8	Native	357	5561.3	4.20	233.9	272.9	78.30	27.06	51.24
No. 10	2	1-2 B.Hol	365	4270.0	3.63	164.2	179.9	51.60	21.98	29.62
No. 11	7	Native	327	4470.0	3.48	205.1	239.2	67.60	21.98	45.62
No. 12	2	1-2 B.Hol	242	2787.3	4.66	130.0	154.6	40.55	21.98	18.57
No. 16	6	1-2 B.Hol	214	2953.8	3.63	107.7	125.7	36.25	21.98	13.27
No. 17	3	1-2 B.Hol	274	3895.2	3.63	141.7	165.3	48.61	23.30	25.31
No. 18	3	1-2 B.Hol	245	4074.1	3.98	162.5	189.5	57.18	24.72	32.46
No. 19	2	1-2 B.Hol	306	4471.2	3.60	159.8	186.4	51.47	25.46	26.01
Pietertje Dak. Mechthilde	3	PB Hol	276	4522.6	3.50	158.2	184.5	50.87	25.60	25.27
No. 21	4	1-2 B.Hol	258	3757.3	3.58	144.7	168.8	47.33	23.44	23.89
No. 23	2	1-2 B.Hol	237	2044.6	4.49	91.8	102.1	29.52	23.44	6.08
North Star Inka	2	PB Hol	250	3811.4	3.17	121.0	141.1	39.31	23.44	15.87
Average of all cows	4.0		293	5015.9	3.79	191.0	222.8	64.10	26.90	37.20

TABLE IX.—HERD OF F. C. MICHAELS. RECORD OF PRODUCTION FOR YEAR 1919.

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
No. 1.....	2	1-2 B.Hol	335	4275.2	4.38	187.4	218.6	63.88	35.82	28.06
No. 3.....	2	1-2 B.Hol	365	5024.6	3.75	188.5	219.9	63.64	36.12	27.52
No. 7.....	2	1-2 B.Hol	345	4959.0	3.56	176.5	205.9	58.67	33.60	25.17
No. 8.....	7	Native	303	5127.4	4.05	207.8	242.4	70.19	32.14	38.05
Cordova Barb De Kol.....	7	PB Hol	329	7004.6	3.50	22.90	267.1	75.63	38.49	37.14
Barbetta Dak. De Kol.....	2	PB Hol	324	4698.3	3.50	164.2	191.5	55.60	31.48	24.12
No. 22.....	2	1-2 B.Hol	286	5993.8	4.03	241.8	282.1	83.26	36.22	47.04
Average of all cows.....	3.4		326	5297.5	3.82	199.3	232.5	67.26	34.82	32.44

TABLE X.—HERD OF WM. NEAS. RECORD OF PRODUCTION FOR YEAR 1919.

Bessie.....	2	Native	238	2542.6	3.60	91.3	106.5	28.41	24.45	3.96
Red.....	8	Native	273	4473.2	3.81	180.7	210.8	57.66	27.51	30.15
Grate.....	8	Native	289	3909.3	3.56	139.6	162.8	47.72	28.90	18.82
Pet.....	8	Native	304	6471.4	3.94	255.3	297.8	87.05	34.34	52.71
Minnie.....	5	Native	329	5793.1	3.79	219.8	256.4	72.61	26.36	46.25
Grate.....	4	Native	212	2749.2	3.60	100.9	117.7	31.23	11.20	20.03
Rose.....	7	Native	216	1674.4	4.10	68.5	79.9	21.98	24.10	2.12
White.....	6	Native	328	4319.2	3.66	158.1	174.4	58.60	27.02	31.58
Queen.....	2	Native	239	3040.7	3.78	115.1	134.2	36.21	29.65	6.56
Bessie.....	4	Native	304	6219.5	3.63	226.0	263.6	74.66	30.20	44.46
Nellie.....	6	Native	276	7164.0	4.03	289.2	337.4	97.26	32.41	64.85
Dora Iuka Pietertje.....	2	PB Hol	303	5328.0	3.62	193.3	225.5	66.04	31.19	34.85
Bergh Litth Pietertje.....	2	PB Hol	273	6978.3	3.62	251.9	293.8	79.13	31.10	48.03
Darkie.....	2	Native	267	2054.8	4.20	130.9	162.7	43.53	26.43	17.10
Mollie.....	2	Native	247	3298.2	3.50	117.6	137.2	36.40	25.11	11.29

Jerd	2	Native	243	2861.3	3.30	96.1	112.1	28.84	23.11	5.73
Bob	6	Native	298	4852.1	3.60	177.2	206.7	57.46	29.77	27.69
Star	4	Native	238	4672.4	3.11	145.4	169.6	45.25	25.11	20.14
Lucy	4	Native	233	4579.9	4.00	186.6	217.7	57.68	25.11	32.57
Average of all cows	4.5		268	4867.4	3.70	165.4	192.9	54.09	27.00	27.31

TABLE XI.—HERD OF ROBERT RUSCH. RECORD OF PRODUCTION FOR YEAR 1910

Altona Woodland	2	PB Hol.	267	3444.4	3.40	116.6	136.0	38.07	28.88	9.20
Beauty	9	Native	237	3558.0	4.21	149.8	174.7	50.07	27.76	22.31
Scarlet	6	Native	273	4811.4	3.75	180.4	210.4	58.24	29.30	28.94
Boot Jack	7	Native	304	4574.7	4.25	195.0	227.5	66.67	30.48	36.19
Crook Horn	8	Native	247	3142.2	3.65	114.8	133.9	37.50	27.10	10.40
Daisy	9	Native	286	4856.8	4.00	194.9	227.3	62.52	27.10	35.42
Jessie	5	Native	243	2744.4	4.10	112.5	131.2	38.33	28.50	9.83
Kicker	6	Native	289	3483.3	4.02	140.4	163.8	46.10	30.52	15.53
Lucy	7	Native	273	2993.3	4.00	121.4	141.6	39.73	28.88	10.85
Pettie	7	Native	302	4296.0	4.86	209.0	244.0	68.77	30.12	38.65
Rosie	5	Native	328	2724.6	4.71	128.4	149.8	43.05	26.12	16.93
Three	8	Native	294	6283.7	3.83	240.8	280.9	80.81	36.50	44.31
Older	8	Native	300	5124.0	4.00	208.5	243.2	69.73	31.88	38.75
White Head	6	Native	297	4029.0	3.55	143.5	167.5	47.66	29.78	18.08
Average of all cows	6.6		281	4004.7	4.02	161.1	187.9	53.38	29.49	23.96

TABLE XII.—HERD OF DIET SCHWARTING RECORD OF PRODUCTION FOR YEAR 1910.

Skylark Ormsby De Kol H	6	PB Hol	231	7345.4	3.80	279.8	326.4	96.28	41.58	55.70
Daisy Johanna Ormsby	6	PB Hol	335	7012.3	3.90	274.5	320.2	91.89	38.86	53.03
No. 3	8	Native	304	5221.7	3.93	205.4	239.6	71.43	34.28	37.15
No. 6	6	Native	335	4261.0	4.10	175.0	204.1	58.44	33.36	25.08
No. 6	7	Native	365	6176.6	3.86	241.0	281.1	82.49	36.06	46.48
No. 7	8	Native	243	3283.0	4.63	152.2	177.5	51.14	29.58	21.56
No. 8	5	Native	212	3605.5	3.60	130.0	151.6	45.45	33.44	12.01
No. 9	5	Native	243	4238.8	4.50	180.9	211.0	52.24	31.68	20.56
No. 13	6	Native	243	3721.8	3.75	139.8	163.1	48.13	31.00	17.13
Grace Ormsby De Kol	6	PB Hol	229	6771.4	3.84	260.3	303.7	83.68	35.46	48.12

Name of Cow	Age	Breed	Milking during year	Milk		Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
				days	lbs.		lbs.	lbs.	dols.		
No. 16	6	Native	306	4181.1	4.31	180.5	210.6	58.19	33.97	24.22	24.22
No. 17	4	Native	245	3181.5	4.51	143.6	167.5	45.56	32.92	12.64	12.64
Grace Dak. De Kol.	3	PB Hol	273	5113.3	3.81	194.8	227.2	63.21	35.85	27.36	27.36
Queen Dak. Colantha	3	PB Hol	260	4546.0	3.81	173.6	202.5	56.33	34.28	22.05	22.05
No. 22	7	Native	214	4058.8	3.86	157.0	183.1	49.93	32.48	17.45	17.45
No. 23	3	1-2 B. Hol	245	3435.9	3.71	127.5	148.7	41.21	31.00	11.21	11.21
No. 10	6	Native	275	4360.0	4.20	183.3	218.8	64.16	30.68	33.48	33.48
Average of all cows	5.5		268	4736.1	4.00	188.1	219.8	62.33	33.91	28.54	28.54

TABLE XIII.—HERD OF JOHN TELLMAN. RECORD OF PRODUCTION FOR YEAR 1910.

Stocking Leg	6	Native	333	3892.4	4.47	174.1	203.1	54.65	30.64	24.01	24.01
Etta Colanthur De Kol.	2	PB Hol	229	3924.3	3.80	148.8	173.6	44.99	30.64	14.35	14.35
Topsy	7	Native	314	5150.1	4.55	234.6	270.3	78.67	35.30	43.37	43.37
White Head	9	Native	277	5089.0	4.37	216.9	253.0	72.89	36.24	36.25	36.25
No. 6	10	Native	335	4437.6	4.62	205.3	239.5	67.43	28.54	38.89	38.89
Slicky	8	Native	304	3647.1	4.51	165.3	192.8	52.97	29.94	23.03	23.03
Buttermaker	7	Native	228	3821.7	4.00	154.8	180.6	50.41	29.42	20.99	20.99
Brandt	9	Native	212	3464.7	3.39	117.7	137.3	36.94	27.66	9.28	9.28
Lue	9	Native	328	3264.0	4.60	142.4	166.1	44.84	27.92	16.92	16.92
Ribs	6	Native	238	1662.6	3.72	61.9	71.2	19.60	26.56	6.96*	6.96*
Short-tail	217	Native	3797.4	4.83	183.7	214.3	61.22	31.22	30.00	30.00	30.00
Brownie	9	Native	289	5518.4	4.06	224.5	261.9	72.83	31.92	40.91	40.91
Short-teat	10	Native	361	4221.9	4.34	183.4	213.9	60.10	33.02	27.08	27.08
Schimmel	8	Native	330	4897.8	3.80	190.0	221.4	60.65	31.92	38.73	38.73
Brono	10	Native	300	4775.2	4.66	222.7	259.8	71.90	30.82	41.08	41.08
Spory	7	Native	243	4194.4	4.11	175.7	205.0	54.82	28.76	26.06	26.06
Old White Head	12	Native	106	5593.3	4.10	228.8	266.9	75.08	31.46	43.46	43.46
Black	3	1-2 B. Hol	258	2607.3	4.31	112.5	131.2	34.24	28.62	5.62	5.62
*Loss. Average of all cows	7.5		270	4043.9	4.22	171.7	200.1	55.30	30.49	25.31	25.31

TABLE XIV.—HERD OF WM. TELLMAN. RECORD OF PRODUCTION FOR YEAR 1910.

	2	1-2 B.Hol	245	4780.4	3.81	181.1	211.2	56.00	24.42	31.68
White-face	7	Native	333	6457.8	4.00	287.8	300.7	86.27	32.74	53.53
Rickey	4	Native	365	4811.0	4.70	227.0	261.5	75.90	26.16	49.74
Baby	9	Native	273	6293.9	4.20	264.6	808.7	93.67	32.14	61.53
Nellie	10	Native	243	3937.6	3.79	146.0	170.3	49.30	27.52	21.78
Butter	9	Native	242	4361.0	4.24	266.3	240.7	73.23	29.34	43.94
White-head	8	Native	273	4668.1	4.00	188.4	219.8	65.03	23.88	36.15
Lily	8	Native	242	4968.3	3.43	170.6	199.0	61.38	29.88	31.50
Long-Leg	13	Native	303	6690.6	3.50	234.5	273.5	81.74	32.68	49.05
Bessie	8	Native	334	7417.1	3.87	287.7	835.6	99.58	32.96	67.62
Spottie	7	1-2 B.Hol	334	6003.7	3.44	206.6	241.0	75.00	30.02	44.98
Ida	6	PB Hol	304	10085.7	3.64	360.9	421.0	123.19	41.66	81.53
Sally De Kol Ormsby	6	Native	211	2969.8	4.26	126.5	147.6	38.62	22.66	15.96
No. 14	3	1-2 B.Hol	273	2446.3	4.13	102.1	119.1	32.92	23.22	9.70
Queen	3	1-2 B.Hol	273	3913.9	4.13	151.5	198.4	56.40	24.62	31.78
Nance	7	Native	272	4572.9	3.76	182.2	212.5	55.56	24.30	31.26
Stella	4	1-2 B.Hol	272	4089.9	3.98	163.2	180.4	54.06	23.22	30.84
Lizzie	3	1-2 B.Hol	303	5637.2	3.82	215.7	251.6	68.91	26.32	42.59
Blacky	3	1-2 B.Hol	306	3960.6	3.65	144.5	168.5	46.51	23.22	23.29
Cherry										
Average of all cows	6.3		284	5172.3	3.91	201.4	234.7	68.06	28.20	39.91

TABLE XV.—THE AVERAGE PRODUCTION OF EACH HERD
DURING THE YEAR 1910

Owner of Herd	Average Age of cows		Number in Herd	Milk		Average Test	Fat		Butter	Value of Fat		Cost of Feed	Profits
	yr.	lbs.		lbs.	pr ct.		lbs.	dols.		dols.			
Benker, Herman	6.3	4740.0	22	4740.0	4.04	195.9	228.6	65.98	33.66	32.28			
Christiansen, John & Son.	6.6	4958.6	15	4958.6	3.66	184.8	215.5	62.51	28.06	34.45			
Gaebel, Frank	6.2	3412.7	17	3412.7	3.88	181.9	153.8	44.14	27.25	16.10			
Holle, George	6.0	9564.8	2	9564.8	3.86	332.4	388.3	108.80	36.50	72.90			
Holle, Henry	5.2	4895.1	21	4895.1	3.71	181.7	210.8	61.55	28.49	38.05			
Klusman, Chas.	5.4	4698.7	9	4698.7	3.87	170.0	197.0	56.63	27.06	29.99			
Klusman, John	6.8	4655.4	18	4655.4	3.92	182.7	212.7	61.69	28.26	33.48			
Kroeger Bros.	4.0	5015.9	18	5015.9	3.79	191.0	222.8	64.10	26.90	37.20			
Micheals, F. C.	3.4	5297.5	7	5297.5	3.82	199.3	232.5	67.26	34.82	32.44			
Ness, Wm.	4.5	4367.4	19	4367.4	3.70	165.4	192.9	54.09	27.00	27.31			
Rusch, Robert	6.6	4004.7	14	4004.7	4.02	161.1	187.9	53.38	29.49	23.96			
Schwartz, Diet.	6.5	4736.1	17	4736.1	4.00	188.1	219.8	62.33	33.91	28.54			
Tellman, John	7.5	4043.9	19	4043.9	4.22	171.7	200.1	55.30	30.49	25.31			
Tellman, Wm.	6.3	5172.3	19	5172.3	3.91	201.4	234.7	68.06	28.20	39.91			
Average of all cows	*5.8	4634.9	217	4634.9	3.89	180.3	210.2	60.24	29.46	30.83			
*Four missing.													

*Four missing.

**TABLE XVI SHOWING THE AVERAGE DAILY RATION FED TO
THE COWS IN THE CIRCUIT DURING THE MONTH OF
JANUARY 1910.**

Owner of Herd	Millet Hay	Prairie Hay	Corn Stover	Barley and Oats	Bran
	lbs.	lbs.	lbs.	lbs.	lbs.
John Christiansen & Son	6.2	10.3	4.1	2.5	2.5
Wm. Tellman	10.6	10.0	8.2	3.5	
Chas. Klusman	11.9	9.3	8.2	3.4	
Diet Schwarting	13.3	12.3		4.6	5.3
Kroeger Bros.	11.6	10.9	7.3	4.9	
John Tellman	11.4	11.4	6.6	3.6	
Henry Holle	8.0	10.4	7.2	3.4	
Frank Gaebe	11.3	13.2	6.1	3.3	
John Klusman	11.0	9.0	7.1	4.6	
Wm. Neas	12.1	12.1	6.0	2.0	
Chas. Holle	10.0	11.0	10.0	5.0	
Robt. Rusch	7.6	7.1	7.5	1.5	1.5
F. C. Micheals	12.0	12.3	6.6	2.1	2.0
Herman Benker	12.8	13.8	*6.6	4.1	

†Wheat Straw. *Flax Straw.

TABLE XVII.—HERD OF HERMAN BENKER. RECORD OR PRODUCTION FOR YEAR 1911.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat dols.	Total Cost of Feed dols.	Profits dols.
Stella Maxum DeKol	3	PB Hol	319	6056.7	3.57	226.3	254.0	62.96	36.87	26.09
Pet No. 17	3	B Hol	306	4730.6	3.62	174.8	203.9	46.92	25.09	21.83
Kate	4	Gr Hol	256	3418.0	4.20	143.8	167.8	42.65	33.58	9.07
Manda	4	Gr Hol	272	4432.3	4.04	179.2	209.0	50.46	29.84	20.62
Mary	4	Gr Hol	365	4491.8	3.91	175.7	206.0	46.85	37.57	98.28
Lucy	2	Gr Hol	319	4453.3	4.16	185.2	216.0	48.68	36.91	11.77
Butter cup	4	Gr Hol	324	4559.6	3.96	180.8	210.9	50.95	37.85	13.10
Ester	4	Gr Hol	231	2032.4	4.56	92.8	108.2	25.19	30.48	-5.29
Slicky	7	Native	365	6943.8	4.06	281.9	328.8	78.50	38.89	39.61
Mouse	7	Native	331	6874.6	4.17	286.6	334.3	84.82	35.36	49.46
Rosie	9	Native	276	5702.0	3.66	218.9	255.3	55.74	36.21	19.53
Bloody	3	Native	319	6120.5	4.63	281.7	328.7	80.71	40.67	40.04
Lizzie	5	Native	239	3800.8	4.96	154.3	280.0	46.38	28.12	18.26
Mollie	9	Native	238	4564.8	4.01	182.9	213.3	57.67	38.92	18.76
Fonny	6	Native	365	7057.7	4.18	295.9	345.2	80.83	39.85	41.48
Grata	8	Native	304	5098.0	4.18	213.7	249.3	54.89	38.25	16.64
Pinke	9	Native	290	4913.6	4.22	207.4	242.0	55.00	31.59	23.41
Spitz	8	Native	291	4375.0	3.81	166.9	194.7	44.11	31.29	12.82
Short Test	11	Native	254	3721.3	3.91	146.8	270.0	45.73	33.22	12.51
Fanny	11	Native	253	4607.9	4.17	192.4	224.4	47.90	36.85	11.05
Jennie	9	Native	329	5869.1	4.47	262.7	311.5	74.67	33.94	40.73
Average of all cows	6.4		297	4943.5	4.11	202.3	245.3	56.26	34.80	25.70

TABLE XVIII.—HERD OF JOHN CHRISTIANSEN & SON. RECORD OF PRODUCTION FOR YEAR 1911.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat dols.	Total Cost of Feed dols.	Profits dols.
Aggie Belle Volkline	5	PB Hol	330	6904.3	3.20	222.6	259.7	61.42	28.96	32.46
De Vries Hengervold DeKol	8	PB Hol	366	7891.5	3.23	256.4	297.9	66.57	27.81	29.26
Butterine Gem DeKol	8	PB Hol	365	7263.8	3.42	248.6	290.0	65.31	28.96	36.35

Princess Dakota DeKol	4	PB Hol	365	8280.8	3.17	262.8	316.6	70.51	28.96	41.55
Pet	3	Gr Hol	350	5627.5	3.58	199.0	232.1	50.96	27.31	23.65
Nancy	3	Gr Hol	330	5493.5	3.30	181.6	211.9	48.04	28.96	19.08
Blacky	3	Gr Hol	314	3879.5	3.58	138.5	161.5	34.50	27.31	7.19
Maggie	3	Gr Hol	277	4885.0	3.32	168.5	190.7	39.54	27.31	12.23
Beauty	8	Native	311	6504.3	3.16	206.1	240.4	56.79	28.96	27.83
Beattie	8	Native	309	5565.9	3.50	194.8	227.2	48.75	27.31	21.44
Queen	10	Native	309	5465.9	3.76	206.8	241.2	51.15	27.31	23.84
Lotty	9	Native	365	6534.5	4.42	239.4	337.6	74.66	27.31	47.35
Jessie	11	Native	365	5223.0	3.12	163.0	190.1	42.00	27.31	14.59
Flory	8	Native	319	5107.0	3.41	174.0	203.0	49.17	28.96	20.21
Average of all cows	6.1		331	6044.7	3.43	207.5	242.8	54.24	28.01	26.21

TABLE XIX.—HERD OF FRANK GAEBE. RECORD OF PRODUCTION FOR YEAR 1911

Johanna DeKol Poeh	4	PB Hol	325	6052.1	3.11	139.4	222.6	50.96	29.28	21.68
Indi Pense Surprise	3	PB Hol	345	6329.3	2.88	133.4	213.9	50.45	29.28	21.17
Spottie	4	1-2 B.Hol	268	3794.5	3.41	129.6	151.2	39.29	21.80	17.49
Star	5	1-2 B.Hol	241	2829.1	3.65	86.0	99.1	26.39	21.80	4.59
Mary	5	1-2 B.Hol	216	1456.4	3.63	53.0	61.8	13.11	21.36	8.25
Queen	5	1-2 B.Hol	304	2914.4	3.56	104.0	121.3	26.77	21.36	4.41
Redy	9	Native	292	4961.5	3.96	194.5	226.9	47.98	27.96	19.97
Bloomie	8	Native	319	5251.3	3.58	188.4	219.8	51.11	26.56	24.55
White	10	Native	305	3654.6	4.38	159.8	186.4	41.14	26.54	14.60
Princess	10	Native	300	4019.1	3.83	154.0	179.6	39.08	26.54	12.54
Babe	8	Native	293	4061.3	3.52	142.8	166.6	38.14	24.08	14.06
Cowboy	8	Native	197	2908.6	3.62	106.2	122.7	33.46	21.80	11.66
Average of all cows	6.5		232	3930.1	3.59	140.7	164.3	38.06	24.86	13.20

TABLE XX.—HERD OF GEORGE HOLLE. RECORD OF PRODUCTION FOR YEAR 1911.

Daisy Ormaby Johanna	7	PB Hol	302	9529.7	3.65	349.9	408.2	102.56	38.06	64.50
No. 6	7	PB Hol	309	7786.2	3.90	304.7	355.5	84.21	38.72	45.49
Queen	2	Gr Hol	269	5363.2	3.96	211.5	246.7	64.93	31.56	23.37
Spot	2	Gr Hol	251	4803.8	4.40	212.4	247.8	57.11	28.72	28.39
Flip	2	Gr Hol	247	5002.8	4.14	207.3	241.8	56.04	29.81	25.23
Sly	2	Gr Hol	226	3263.2	4.00	132.9	155.1	34.42	28.72	5.70
Average of all cows	3.6		255	5558.1	4.00	236.4	275.8	64.71	32.59	32.11

TABLES XXI.—HERD OF HENRY W. HOLLE. RECORD OF PRODUCTION FOR YEAR 1911.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat dols.	Total Cost of Feed dols.	Profits dols.
Kaan Marie of Edgetown.	8 yrs.	PB Hol	319	8801.9	3.39	298.8	348.6	90.62	30.60	60.12
Kaan Marie of Dakota.	2	PB Hol	301	5134.9	3.39	174.2	201.2	45.28	33.97	11.31
North Star Bess.	4	PB Hol	295	4679.6	3.26	152.7	178.1	44.22	30.62	13.60
Tressie.	3	Gr Hol	295	4928.3	3.79	186.8	217.9	49.12	25.38	23.74
Slickie.	3	Gr Hol	319	7766.2	3.57	277.1	321.6	79.69	29.84	49.85
Dora.	5	Gr Hol	332	5880.4	3.53	207.9	242.5	54.25	28.44	25.81
Daisy.	5	Gr Hol	239	4713.3	3.41	159.9	186.5	44.58	25.18	19.40
Blackie.	5	Gr Hol	320	6065.5	3.62	221.1	257.9	66.24	29.72	36.52
Selma.	2	Gr Hol	212	1708.1	4.13	72.50	84.5	18.38	29.70	10.32
Pinkey.	2	Gr Hol	304	5305.1	3.59	190.8	222.6	55.91	28.36	26.55
Rosie.	3	Gr Hol	269	3368.4	3.36	113.2	132.0	31.06	17.20	13.86
Lilly.	4	Gr Hol	299	5167.2	3.72	192.5	224.5	59.24	29.06	30.18
Fanny.	4	Gr Hol	241	3952.5	3.62	143.2	167.0	44.03	30.12	18.91
Minnie.	5	Gr Hol	265	4423.6	3.28	161.4	188.3	42.44	24.82	17.62
Lizzy.	7	Native	304	6196.1	3.66	227.3	165.1	61.70	30.06	31.64
Blasie.	6	Native	312	4688.0	3.90	182.7	213.1	51.74	27.00	24.74
Nellie.	8	Native	283	4881.8	3.80	186.1	217.1	52.53	26.64	26.89
Batsie.	9	Native	212	5066.7	3.94	199.7	232.9	57.92	29.72	28.20
White Face.	8	Native	286	4873.5	3.88	188.4	219.8	53.21	24.93	28.23
Floesie.	6	Native	288	4262.1	3.72	158.6	185.1	41.73	24.86	16.87
Average of all cows.	4.9		284	5092.6	3.62	184.7	210.3	52.19	27.75	24.43

TABLE XXII.—HERD OF CHAS. KLUSMANN—SR., RECORD OF PRODUCTION FOR YEAR 1911.

Alma Marie.	7	PB Hol	324	7243.5	4.08	295.5	344.7	79.76	30.20	49.56
Erma.	3	1-2 B.Hol	224	2592.6	3.59	93.1	108.6	27.17	12.16	15.01
Blue.	3	1-2 B.Hol	244	2724.7	4.00	111.4	130.3	31.64	12.16	19.48
Pink.	3	1-2 B.Hol	235	3117.9	4.10	127.7	149.0	36.34	12.16	24.18

Blackie	3	1-2 B.Hol	280	2455.8	4.88	107.6	125.5	28.04	27.61	43
Nellie	5	1-2 B.Hol	287	4173.6	3.64	152.3	177.6	39.97	29.39	10.58
Grace	4	1-2 B.Hol	294	4652.2	3.89	180.1	210.0	48.03	28.03	20.00
Scrub	4	1-2 B.Hol	308	4847.1	3.57	166.2	193.9	51.50	26.95	24.55
Lillie	2	1-2 B.Hol	324	5031.7	3.45	178.9	202.8	52.62	27.88	24.74
Minnie	3	1-2 B.Hol	279	6598.8	3.44	227.3	261.8	66.59	26.02	40.57
White Head	3	1-2 B.Hol	297	4248.6	4.31	188.2	213.7	48.36	26.80	21.56
Gray	3	1-2 B.Hol	320	6240.4	3.65	227.9	265.8	64.11	27.88	36.28
Sucker	9	Native	321	5831.1	3.71	216.3	252.3	61.06	27.88	33.18
No. 9 Selma	7	Native	246	4568.2	3.76	171.3	199.8	42.98	29.05	13.93
Rosie	8	Native	323	4682.4	4.15	194.5	226.9	51.77	28.78	23.04
Average of all cows	4.4		285	4594.6	3.84	175.2	204.1	48.66	24.86	23.80

TABLE XXIII.—HERD OF JOHN KLUSMAN, RECORD OF PRODUCTION FOR YEAR 1911.

Baby Bahias Snowflake	7	PB Hol	365	7079.7	3.19	226.5	264.2	62.14	30.94	31.20
*Skylark Dakota Hengervild	4	PB Hol	338	7947.4	3.88	268.7	313.5	76.89	31.24	45.65
Bessie	4	1-2 B.Hol	245	5046.7	3.48	172.0	200.6	46.31	25.50	20.81
Bird	3	1-2 B.Hol	271	3662.6	4.18	153.2	178.7	43.60	25.50	18.10
May	4	1-2 B.Hol	308	5479.1	3.62	192.2	224.2	57.05	29.88	27.17
Rosie	4	1-2 B.Hol	351	6388.7	3.35	215.3	251.1	60.31	31.24	29.07
Wheely	4	1-2 B.Hol	333	6615.2	3.36	224.7	262.1	64.54	30.53	33.96
Pet.	3	1-2 B.Hol	247	3779.9	3.43	181.0	152.8	36.99	26.50	10.49
Billie	3	1-2 B.Hol	321	5642.8	3.55	199.6	232.8	53.82	30.43	23.38
Bloome	3	1-2 B.Hol	285	4036.0	3.44	139.6	162.8	36.63	29.73	6.90
Sun Light	2	3-4 B.Hol	223	2916.0	3.78	110.4	128.8	32.17	13.69	18.48
Jersey	9	Native	308	6198.3	3.62	244.7	285.5	71.04	30.28	40.76
Blackie	8	Native	310	5790.2	3.87	224.5	261.9	53.10	30.94	27.16
Brownie	8	Native	324	6214.8	3.85	239.3	289.2	63.08	31.09	31.99
Bobtail	9	Native	355	4545.9	4.44	202.0	235.6	66.40	30.94	24.23
Marble	9	Native	342	6136.4	3.88	238.5	278.2	66.40	31.24	35.16
Scrub	9	G Her	355	5611.1	4.17	234.5	273.1	70.57	30.58	39.99
Star	8	Native	249	3996.5	3.85	154.2	179.9	43.28	30.58	12.65
Shorthorn	8	Native	272	5063.3	3.71	188.0	218.3	50.96	31.24	19.72
White Face	9	Native	272	4304.7	3.71	180.1	186.7	40.25	31.09	9.16
Average of all cows	5.8		303	5322.5	3.68	195.9	229.0	54.46	29.16	25.30

* Milked from only two tests from Oct. 1, 1911.

TABLE XXIV.—HERD OF KROEGER BROS., RECORD OF PRODUCTION FOR YEAR 1911.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat dols.	Total Cost of Feed dols.	Profits dols.
Pieterje DeKol Mechthilde	6	PB Hol	314	10118.8	3.83	346.9	404.7	100.91	34.44	66.47
Junette Madrigal	6	PB Hol	291	7641.2	3.78	289.2	337.4	88.07	34.44	53.63
Countess Elgin Belle Pet.	7	PB Hol	320	10874.5	3.64	396.6	462.7	119.28	39.69	79.69
Pieterje Dakota Mechthilde	4	PB Hol	310	6450.3	3.58	231.2	269.7	65.59	24.26	41.33
Anzalope	3	Gr Hol	298	6275.0	3.74	230.5	268.9	69.46	26.41	42.95
Floxy	3	Gr Hol	304	6752.2	3.75	263.6	295.8	73.44	26.51	46.93
Rosie	3	Gr Hol	310	5732.9	3.63	208.1	242.8	61.65	24.04	37.61
Queen	3	Gr Hol	282	3916.0	4.76	183.4	213.9	51.97	22.46	29.51
Blackie	4	Gr Hol	262	4944.2	3.66	180.4	210.4	54.23	22.90	31.33
Fernie	3	Gr Hol	245	4255.2	3.87	143.7	167.6	37.98	21.80	16.18
White	3	Gr Hol	281	4555.2	3.92	181.9	212.2	64.49	22.46	32.03
Fanny	5	Gr Hol	295	4299.6	3.72	160.2	186.9	44.68	24.46	20.22
Duchess	3	Gr Hol	316	3624.5	4.28	153.9	179.5	42.51	24.86	17.65
Commoner	8	Native	304	4749.7	4.10	194.7	227.1	54.38	23.56	30.82
Average of all cows	4.4		295	6015.7	3.80	225.3	262.8	65.61	26.59	39.01

TABLE XXV.—HERD OF F. C. MICHEALS, RECORD OF PRODUCTION FOR YEAR 1911.

Pauline Clothilde Rosch	2	PB Hol	306	6168.9	3.23	199.8	233.4	58.62	37.73	20.89
Cordova Barbetta DeKol	7	PB Hol	300	10050.3	3.31	333.0	388.5	93.16	34.98	58.18
Barbetta Dakota DeKol	3	PB Hol	321	5256.5	3.21	173.2	202.0	52.52	26.09	26.43
Bessie	3	1-2 B.Hol	306	4567.3	3.62	180.1	210.1	53.93	31.92	22.01
Ruth	2	1-2 B.Hol	311	4997.6	3.66	183.0	213.5	51.39	32.31	19.08
Florence	2	1-2 B.Hol	308	6096.1	3.62	221.0	257.8	60.18	33.66	26.52
Queen	2	1-2 B.Hol	285	5220.4	3.75	195.8	228.4	52.05	30.17	21.89
Star	3	1-2 B.Hol	307	5581.8	3.34	186.5	217.5	51.49	32.31	19.13

Jessie	3	312	4452.6	4.27	190.0	221.6	54.79	28.97	26.82
No. 8.	8	271	4363.5	4.06	177.5	207.0	54.70	26.09	28.61
Elate	7	315	5168.9	4.00	209.9	248.3	61.41	26.09	36.32
Average of all cows	3.8	303	5665.8	3.64	204.5	238.9	58.56	30.93	27.72

TABLE XXVI.—HERD OF WM. NEAS, RECORD OF PRODUCTION FOR YEAR 1911.

Dora Inka Pieterje	3	305	4918.1	3.45	170.0	198.3	39.41	36.93	2.48
Beryl Lilith Pieterje	3	286	6664.7	5.27	351.4	409.9	86.99	37.20	49.79
Bessie	3	264	3859.8	3.97	133.2	155.4	36.95	31.58	5.37
Red	9	274	3662.3	3.76	137.7	160.6	38.24	28.84	4.40
Gray	12	245	2253.8	3.51	80.2	93.5	20.10	28.60	8.50
Pet	9	345	6217.4	3.36	210.6	245.7	58.19	31.29	26.80
Minnie	6	362	7171.0	3.50	251.3	293.2	64.99	28.72	36.27
Jessie	2	305	3905.0	3.70	144.6	168.7	37.21	25.19	12.02
Grate	5	291	4185.7	3.87	162.1	189.1	41.05	26.84	14.21
Rose	8	214	4685.5	3.16	148.2	172.9	39.88	26.84	13.04
White	7	324	4571.5	3.67	167.8	195.7	45.90	27.69	18.21
Bessie	5	276	6414.8	3.50	224.6	262.0	56.88	28.03	28.85
Nele	7	247	4215.5	3.60	151.6	176.8	37.37	29.08	8.29
Darkie	5	305	3063.7	4.10	128.3	149.7	31.29	26.84	4.45
Mollie	3	243	4230.0	3.44	145.8	170.1	38.30	26.54	11.76
Zerd	3	245	3556.1	3.40	133.7	156.0	35.51	26.54	8.97
Bob	7	305	5426.2	3.33	180.7	220.8	48.56	27.77	20.78
Beauty	2	241	2699.0	3.53	130.7	142.5	33.81	9.20	24.61
Average of all cows	5.5	282	4528.8	3.67	169.5	197.8	43.64	27.98	15.65

TABLE XXVII.—HERD OF ROBERT RUSCH, RECORD OF PRODUCTION FOR YEAR 1911.

Altona Woodland Beryl	3	298	5260.7	3.24	170.8	209.2	44.62	27.78	16.84
Beauty	4	304	4832.6	3.92	189.8	221.4	48.67	29.78	18.89
Brown	3	331	5753.3	3.73	214.6	250.4	64.09	28.68	25.41
Boot Jack	8	304	5398.9	3.87	210.0	245.0	56.06	28.68	27.38
Crook Horn	8	324	4826.1	3.46	149.8	178.0	36.91	29.78	10.13
Jessie	6	239	3442.3	4.10	141.1	164.6	43.34	28.68	14.66

Name of Cow	Age	Breed	Milking during year		Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
			days	lbs.		lbs.	lbs.	dols.		
Kicker	7	Native	365	3984.6	4.64	184.8	225.6	51.72	29.34	22.38
No. 14	9	Native	237	3088.6		123.2	143.7	30.04	29.34	70
Pet	4	Native	334	5455.5	4.12	224.7	262.1	58.69	29.78	28.91
No. 22 Three	9	Native	301	5076.8	3.63	184.7	215.5	45.88	29.34	16.54
No. 23	7	Native	365	4533.2	3.65	165.6	184.2	43.40	29.78	13.62
Bessie	3	Native	334	3541.6	4.00	141.8	165.4	36.73	29.34	7.39
Nancy	2	Native	300	3527.5	3.65	121.7	142.0	31.78	20.96	10.82
Nettie	4	Native	269	4348.4	3.73	162.3	189.4	41.13	25.50	15.63
Average of all cows	5.5		307	4468.9	3.82	170.3	199.7	44.50	28.34	16.37

TABLE XXVIII.—HERD OF D. SCHWARTING, RECORD OF PRODUCTION FOR YEAR 1911.

Skyllark Ormsby DeKol	7	PB Hol	344	7270.0	3.65	255.9	310.2	70.00	36.20	33.80
Daisy Johanna Ormsby	7	PB Hol	365	7537.4	3.58	270.1	315.1	72.01	35.96	36.05
Grace Ormsby DeKol	7	PB Hol	365	9085.2	3.37	306.9	358.0	81.45	34.60	46.85
Queen Dakota DeKol	4	PB Hol	334	6632.1	3.43	227.9	265.8	61.28	35.96	25.32
Queen Dakota Colantha	4	PB Hol	308	4496.1	3.57	160.5	187.2	41.56	33.24	8.32
Whiteface	3	1-2 B.Hol	264	4040.3	3.33	134.6	159.0	36.93	11.36	25.57
Star	2	1-2 B.Hol	275	3597.6	3.48	125.6	148.5	34.62	27.80	6.82
Long Fellow	2	1-2 B.Hol	227	4383.0	3.88	170.2	198.5	48.54	13.50	35.04
Queen	2	1-2 B.Hol	214	2942.4	3.53	110.4	128.8	32.44	12.20	20.24
Black Beauty	4	Gr Hol	334	5477.2	3.34	183.3	213.8	53.79	31.88	21.91
Shorty	9	Native	294	5628.4	3.61	203.5	239.4	59.76	35.96	23.80
Lillie	7	Native	330	5780.1	3.67	211.8	247.1	55.71	35.96	19.75
Rosie	8	Native	302	6147.1	3.68	226.8	264.6	62.30	35.96	26.34
Bobtail	9	Native	300	6757.8	4.04	273.5	319.0	75.22	35.96	39.26
Saucy	7	Native	250	4729.0	3.72	174.5	203.5	47.62	26.44	21.18

Spotty	7	Native	306	6180.4	3.75	204.4	238.4	62.97	30.62	22.45
Brownie	5	Native	245	3589.7	4.05	145.5	169.7	36.06	30.52	5.54
Kicker	8	Native	249	4568.7	3.90	179.4	209.3	45.09	21.40	23.69
Average of all cows	5.6		294	5435.6	3.64	198.6	231.9	53.74	29.19	24.55

XXIX.—HERD OF JOHN TELLMAN, RECORD OF PRODUCTION FOR YEAR 1911.

Etta Colanthes DeKol	4	PB Hol	337	7070.8	3.80	268.9	313.7	72.17	37.30	34.87
Belle	2	1-2 B.Hol	193	3353.9	3.44	115.5	127.4	31.48	14.42	27.06
Fanny	2	Gr Hol	225	3639.3	3.92	144.3	133.3	36.70	15.08	21.62
St. B.	4	Gr Hol	268	4412.0	4.28	188.9	220.3	51.27	27.46	23.81
Black	4	Gr Hol	206	2740.8	4.10	133.2	155.4	40.15	28.72	11.43
Old White Head	13	Native	258	6529.7	4.18	273.5	319.0	68.36	37.30	31.06
Spoty	8	Native	280	4403.5	3.88	204.3	238.3	54.27	37.30	16.97
Brono	11	Native	264	4267.9	3.61	154.1	176.3	37.34	28.12	9.22
Shimmel	9	Native	320	5132.1	3.74	195.3	227.8	51.32	28.12	23.20
Short Test	11	Native	327	4607.2	4.40	217.5	243.7	57.89	37.30	20.59
Brown	10	Native	284	6040.0	3.83	231.5	270.0	64.22	28.12	36.10
Short Tail	7	Native	266	4432.7	4.81	213.4	248.9	57.54	37.30	20.24
Lue	10	Native	288	4278.1	4.27	182.7	213.1	46.88	26.64	20.24
Brandt	10	Native	327	5200.3	4.27	222.5	259.5	58.32	37.30	21.02
Butter Maker	8	Native	300	6291.7	3.91	216.0	287.0	65.28	37.30	27.98
No. 6	11	Native	329	4759.2	4.35	197.4	229.1	57.12	37.30	19.82
Slicky	9	Native	245	4638.6	3.81	176.8	205.2	47.15	26.79	20.36
White Head	10	Native	282	4645.4	4.01	186.6	217.7	53.06	37.30	15.76
Stockingleg		Native	245	4143.4	4.28	177.3	205.8	49.07	26.61	16.36
Topsy		Native	295	4580.9	4.17	191.4	223.3	54.34	37.30	17.04
Average of all cows	7.9		276	4763.3	4.02	196.0	225.8	52.39	31.15	21.73

TABLE XXX.—HERD OF WM. TELLMAN, RECORD OF PRODUCTION FOR YEAR 1911.

Sally DeKol Ormsby	8	PB Hol	350	9599.7	3.56	341.9	398.7	98.08	35.55	62.53
Rose Dakota Ormsby	4	PB Hol	295	5063.7	3.43	174.0	203.0	53.63	30.08	23.55
Sally Dakota Ormsby	5	Gr Hol	314	7514.5	3.72	280.0	326.6	79.33	34.56	44.77
Helen	3	Gr Hol	319	5793.3	3.75	217.4	253.6	60.37	33.52	26.85
White Face	4	Gr Hol	241	4886.6	3.33	163.0	190.0	42.73	26.00	16.73

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Blacky	3	Gr Hol	312	7243.5	3.36	243.9	284.5	66.79	28.72	38.07
Bessie	3	Gr Hol	229	3431.9	3.65	132.5	154.6	37.82	27.36	10.46
Dora	3	Gr Hol	238	4041.0	3.69	145.8	170.1	45.11	27.32	17.79
Neance	3	Gr Hol	249	5445.4	4.10	223.7	161.0	69.31	30.08	39.23
Ida	5	Gr Hol	310	6152.4	3.49	215.1	290.9	60.22	30.08	30.14
Miss Hill	3	Gr Hol	230	2282.0	3.71	84.7	96.8	21.92	17.06	4.86
Jessie	2	Gr Hol	181	3986.1	3.57	140.5	163.9	43.51	11.80	31.71
Longleg	9	Native	238	4669.5	3.52	164.6	192.0	47.01	27.36	19.65
Stella	7	Native	302	5304.2	3.67	195.0	227.1	51.26	29.04	22.22
Spottie	9	Native	309	6785.1	3.70	251.6	293.5	74.84	32.16	42.68
White Head	10	Native	228	5618.2	4.00	225.1	282.6	71.86	31.12	40.74
Butter	11	Native	237	3746.6	3.55	135.5	158.1	42.55	32.82	9.73
Nellie	10	Native	269	5585.0	3.70	206.8	241.1	64.70	30.66	34.04
Baby	5	Native	365	4418.5	4.36	214.7	250.5	57.50	29.42	28.08
Richy	8	Native	274	4217.8	4.17	176.1	225.4	62.37	32.82	29.55
Average of all cows	5.7		274	5289.2	3.69	196.5	227.2	57.54	28.87	28.66

TABLE XXXI. THE AVERAGE PRODUCTION OF EACH HERD DURING THE YEAR 1911.

Owner of Herd	Average Age of Cow	Number in Herd	Milk	Average Test	Fat	Butter	Value of Fat	Cost of Feed	Profit
	yrs.		lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Benker, Herman	6.4	21	4943.5	4.11	202.3	245.3	56.26	34.80	25.70
Christiansen & Son	6.1	14	6044.7	3.43	207.5	242.8	54.24	28.01	26.21
Gaebel, Frank	6.5	12	3890.1	3.59	140.7	154.3	38.06	24.86	13.20
Holle, George	3.6	6	5958.1	4.00	236.4	275.8	64.71	32.59	32.11
Holle, Henry W.	4.9	20	5092.6	3.62	184.7	210.3	52.19	27.75	24.43
Klusman, Chas., Sr.	4.4	15	4594.6	3.84	175.2	204.1	48.66	24.86	23.80
Klusman, John	5.8	20	5322.5	3.68	195.9	229.0	54.46	29.16	25.30
Kroeger Bros.	4.4	14	6015.7	3.80	225.3	262.8	65.61	26.59	39.01
Micheals, F. C.	3.8	11	5665.8	3.64	204.5	238.9	58.56	30.93	27.72
Neas, Wm.	5.5	18	4528.8	3.67	169.5	197.8	43.64	27.98	15.65
Rusch, Robert	5.5	14	4468.9	3.82	170.3	199.7	44.50	28.34	16.37
Schwartz, D.	5.6	18	5435.6	3.64	198.6	231.9	53.74	29.19	24.55
Tellman, John	7.9	20	4763.3	4.02	196.0	225.8	52.39	31.15	21.73
Tellman, Wm.	5.7	20	5289.2	3.69	196.5	227.2	57.54	28.87	28.66
Average of all cows	5.6	223	5106.2	3.76	191.8	223.9	52.85	29.00	24.31

x †Two missing. *One missing.

**TABLE XXXII SHOWING THE AVERAGE DAILY RATION FED
TO THE COWS IN THE CIRCUIT DURING THE
MONTH OF JANUARY 1911.**

Owner of Herd	Millet Hay	Prairie Hay	Wheat Hay	Flax Straw	Corn Stover	Silage	Barley and Oats	Bran
Wm. Tellman	16.6	6.2	16.6		15.5			7.2
Chas. Klusman	16.8	7.7			10.6			2.3
Diet Schwarting		18.0	31.9		15.0	*10.0		1.2
Kroeger Bros	6.0	15.0			8.4	41.3		4.1
Henry Tellman	17.2	11.4			15.0			6.4
Henry Holle	18.0	9.0			11.0	36.0		4.0
Frank Gaebe	9.8	9.0			11.0	20.8		3.1
John Klusman	15.7	12.0			8.0			3.7
Wm. Neas	23.0	16.5				22.3		
Geo. Holle	25.0	12.6	13.3				25.0	6.4
Robert Rusch	9.2	11.3			6.7		8.0	3.1
F. C. Micheals	14.7	10.2		8.5		29.0	6.6	4.4
Herman Benker	21.3			10.3		48.0		6.6
John Christiansen & Son	13.0	7.4	5.3		7.8	31.0	2.2	2.3

*Oat Straw.

TABLE XXXIII. HERD OF CHRISTIANSEN & SON, RECORD OF PRODUCTION FOR YEAR 1912.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test	Fat lbs.	Butter lbs.	Value of Fat	Total Cost of Feed	Profits
	yr.		days		pr. ct.			dols.	dols.	dols.
Dakota Paul DeKol	3	PB Hol	348	6168.2	3.19	196.8	229.6	61.63	32.96	28.67
De Vries Hengerveld DeKol	9	PB Hol	264	6426.5	3.12	200.8	234.2	60.23	30.20	30.03
Butterine Gem DeKol	9	PB Hol	335	5596.9	3.30	184.6	215.3	59.55	32.42	27.13
Princess Dakota DeKol	5	PB Hol	324	6891.1	3.43	236.9	276.3	77.13	32.82	44.31
May	3	1-2 B.Hol	331	5123.0	3.78	193.7	225.9	63.62	32.42	31.20
Roany	3	1-2 B.Hol	294	5821.3	3.47	201.4	234.9	66.03	31.82	34.21
Blacky	4	1-2 B.Hol	307	6592.1	3.03	210.1	245.1	69.17	32.42	36.76
Nany	4	1-2 B.Hol	350	6798.2	3.22	219.2	255.7	69.75	32.42	37.33
Beauty	4	Native	267	6423.7	3.23	208.0	232.6	68.52	32.42	36.10
Aggie Belle Volkoline	6	PB Hol	301	5818.4	3.51	203.8	237.7	65.97	32.42	33.55
Average of all cows	5.0		312	6164.8	3.32	205.5	239.7	66.16	32.23	33.92

TABLE XXXIV.—HERD OF FRANK GAEBE. RECORD OF PRODUCTION FOR YEAR 1912.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test	Fat lbs.	Butter lbs.	Value of Fat	Total Cost of Feed	Profits
	yr.		days		pr. ct.			dols.	dols.	dols.
Sarah	8	Native	334	5537.6	3.87	214.5	250.2	65.60	26.71	38.89
Redy	8	Native	275	4032.6	3.94	169.0	185.5	50.07	25.47	24.60
Bloome	8	Native	283	4698.7	3.78	167.6	195.5	57.10	26.71	30.39
White	10	Native	263	3868.8	4.29	165.2	192.7	51.38	26.71	24.67
Princess	10	Native	266	3816.2	3.98	161.9	178.2	47.98	26.71	21.27
Spottie	5	1-2 B.Hol	329	6505.3	3.41	222.3	259.3	72.85	26.71	46.14
Johanna DeKol Posch	4	PB Hol	332	6664.8	3.32	202.1	235.7	66.38	27.95	38.43
Indi Pense Surprise	5	PB Hol	348	8061.9	2.96	238.9	278.7	78.22	27.95	50.27
Star	5	1-2 B.Hol	315	5400.9	3.34	180.7	210.8	65.96	26.71	39.25
Mary	5	1-2 B.Hol	245	6248.6	3.57	219.2	255.7	72.66	27.95	44.71
Queen	5	1-2 B.Hol	262	6630.8	3.28	217.2	253.4	71.01	27.95	43.06
Babe	7	Native	275	5027.1	3.79	190.6	222.3	58.59	26.71	31.88

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Cowboy	7	Native	248	4166.3	3.58	149.3	174.1	51.75	26.71	25.04
Fly	5	3-4 B.Hol	283	4819.8	3.40	164.0	191.3	55.66	24.84	30.82
Flippen	5	1-2 B.Hol	351	5092.0	3.73	190.5	222.2	59.92	23.30	36.62
Boss	6	1-2 B.Hol	299	4998.8	4.12	206.3	240.6	69.58	25.92	43.66
Pearl	5	1-2 B.Hol	365	4614.9	3.96	183.7	214.3	58.90	25.92	32.98
Average of all cows	6.3		297	5304.3	3.66	189.5	221.2	61.97	26.52	35.45

TABLE XXXV.—HERD OF GEORGE HOLLE, RECORD OF PRODUCTION FOR YEAR 1912.

Daisy Ormsby Johanna	7	PB Hol	365	8824.7	3.37	299.7	349.6	92.54	30.06	62.48
Kaan Jewel Canary Mechthilde	7	PB Hol	304	6890.3	3.73	257.7	300.6	84.71	30.06	54.65
Flip	3	1-2 B.Hol	298	5313.4	4.16	221.1	257.9	65.55	21.06	44.49
Bessie	3	Native	257	5125.5	3.71	190.2	221.9	55.57	27.06	28.51
Star	3	Native	261	4928.2	4.03	198.7	231.8	58.03	28.56	29.47
Jessie	3	1-2 B.Hol	227	2752.2	4.43	113.8	132.7	41.08	30.06	11.02
Glenview Johanna Ormsby	2	PB Hol	298	4120.5	3.65	150.7	176.8	45.59	21.06	24.53
Average of all cows	4.0		287	5422.1	3.86	204.5	238.7	63.29	26.84	36.45

TABLE XXXVI.—HERD OF HENRY HOLLE, RECORD OF PRODUCTION FOR YEAR 1912.

Kaan Marie of Dakota	3	PB Hol	310	6294.3	3.31	208.5	243.2	62.77	25.36	37.41
Minnie	6	1-2 B.Hol	289	5873.0	3.91	230.1	268.4	70.79	24.15	46.64
Lizzy	8	Native	277	5554.4	3.55	198.1	231.1	79.38	26.72	52.66
Blasie	7	Native	202	2434.7	4.17	101.7	118.6	36.98	26.72	19.26
Fanny	5	1-2 B.Hol	271	5301.5	3.61	191.3	223.1	66.24	25.36	39.88
Rosie	4	1-2 B.Hol	285	4009.6	3.31	133.1	155.1	43.33	22.94	20.39

Lilly	6	1-2 B.Hol	294	5044.9	3.63	180.3	210.3	57.19	23.54	33.66
Nellie	9	Native	292	4572.9	3.60	165.3	192.8	50.72	22.78	27.94
Pinky	8	1-2 B.Hol	293	4151.2	4.18	173.7	202.6	57.21	25.36	31.86
Sally	3	1-2 B.Hol	297	4089.7	3.55	145.3	169.5	45.31	24.15	21.16
Batsie	10	Native	231	3003.0	4.00	121.0	141.1	41.48	25.36	16.12
Dakota Marie Kaan	3	PB Hol	336	4315.6	3.67	153.6	186.0	55.04	25.36	29.68
Blackie	6	1-2 B.Hol	325	5961.3	3.47	206.9	241.3	70.48	25.36	45.12
Kaan Marie of Edgetown	9	PB Hol	339	7398.6	3.26	241.7	281.9	79.55	25.36	54.19
Daisy	6	1-2 B.Hol	220	4613.8	3.50	161.7	188.6	48.17	22.33	25.84
Dora	6	1-2 B.Hol	248	6589.6	3.27	215.4	251.3	64.78	23.83	41.24
North Star Bess	5	PB Hol	284	5541.2	3.21	177.9	207.5	55.52	24.91	30.61
Slickie	4	1-2 B.Hol	280	6430.8	3.66	234.6	273.7	70.29	23.64	46.65
Blue Bell	3	3-4 B.Hol	241	3560.0	3.40	121.8	142.1	36.98	23.80	18.13
Bessie	3	1-2 B.Hol	344	4769.0	3.87	184.2	214.9	60.14	24.41	35.73
Tressie	4	1-2 B.Hol	313	5302.0	3.95	229.4	267.6	71.85	22.59	49.26
Spottie	3	1-2 B.Hol	334	3845.5	3.76	145.6	169.8	46.94	23.39	28.55
Average of all cows	5.2		284	4962.5	3.62	178.4	208.1	57.73	24.41	33.72

TABLE XXXVII.—HERD OF CHAS. KLUSMAN, SR., RECORD OF PRODUCTION FOR YEAR 1912.

Dakota of Elmwood	2	PB Hol	346	8837.8	3.60	318.1	371.1	120.31	41.90	60.41
Gray	4	1-2 B.Hol	311	5809.7	3.45	200.6	234.0	67.46	24.96	42.50
Whitehead	4	1-2 B.Hol	260	4369.2	3.64	158.4	184.8	48.97	21.83	27.14
Sucker	10	Native	365	3727.8	3.76	140.5	163.9	51.27	21.83	29.44
Alma Marie 6th Daughter	8	PB Hol	334	6184.3	3.73	234.3	273.3	75.90	22.13	53.77
Minnie	4	1-2 B.Hol	335	6125.6	3.92	240.6	280.7	77.23	22.13	55.10
Elsie	2	1-2 B.Hol	265	3233.8	3.48	112.5	131.2	35.06	14.02	21.04
Rosie	5	1-2 B.Hol	273	5503.1	3.83	210.9	246.0	65.66	22.13	43.53
Selma	8	Native	277	4547.4	3.82	173.8	202.7	55.08	21.83	33.25
Lillie	4	1-2 B.Hol	273	3624.1	4.10	146.2	170.5	44.81	22.13	22.68
Scrub	8	1-2 B.Hol	248	4930.5	3.27	161.3	188.1	53.47	22.13	31.34
Grace	4	1-2 B.Hol	240	5014.0	3.43	174.7	203.8	52.34	21.83	30.51
Blackie	3	1-2 B.Hol	310	5059.3	3.84	194.7	227.1	63.86	25.03	33.83
Pink	3	1-2 B.Hol	269	3949.4	3.60	142.3	166.0	46.10	22.13	23.97
Bluie	3	1-2 B.Hol	294	3237.6	3.80	122.9	143.3	37.15	22.13	15.02
Emma	3	1-2 B.Hol	304	2652.4	3.86	102.2	119.2	32.78	22.13	10.65
Mable	2	1-2 B.Hol	331	3179.8	3.59	114.5	133.5	36.05	22.13	13.92

Name of Cow	Age	Breed	Milking during year		Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
			days	lbs.							
No. 17	2	1-2 B.Hol	299	2815.6	3.44	96.9	113.0	30.10	22.13	7.97	
Baldface	2	1-2 B.Hol	245	2992.7	3.60	107.6	125.5	33.05	11.79	21.26	
Average of all cows	4.2		283	4510.2	3.67	165.9	193.5	53.08	22.43	30.64	

TABLE XXXVIII.—HERD OF JOHN KLUSMAN, RECORD OF PRODUCTION FOR YEAR 1912.

Brownie.....	9	Native	344	5874.0	4.00	241.1	281.2	79.21	23.61	55.60
Bobtail.....	10	Native	258	4776.3	4.06	194.1	226.4	62.43	24.21	38.22
Bessie.....	5	1-2 F.Hol	365	3868.1	3.60	139.5	162.7	45.81	24.21	21.60
Bird.....	4	1-2 B.Hol	282	4310.1	3.61	155.6	151.5	49.61	24.21	25.40
Moonlight and.....	2	1-2 B.Hol	265	3462.2	3.53	121.6	141.8	37.96	15.27	22.69
Marble.....	10	Native	294	4629.8	3.93	182.1	212.4	58.21	24.51	33.70
May.....	5	1-2 B.Hol	292	5014.1	3.48	174.5	203.5	54.83	24.36	30.47
Rosie.....	5	1-2 B.Hol	304	6261.3	3.42	214.4	250.1	69.17	24.51	44.66
Scrub.....	10	Native	291	4656.3	3.76	175.3	204.5	55.88	24.51	31.37
Shorthorn.....	9	Native	266	4366.6	3.82	167.1	194.9	53.22	24.51	28.71
Skylark Dakota Hengerveld.....	5	PB Hol	328	2690.1	4.21	113.4	132.3	36.24	24.51	11.73
Wheely.....	4	1-2 B.Hol	287	3379.9	3.80	128.7	150.1	40.84	24.51	16.33
Bill.....	4	1-2 B.Hol	313	5872.4	3.61	222.0	259.0	69.74	22.86	28.88
Bloomie.....	4	1-2 B.Hol	239	4499.4	3.51	157.7	183.9	51.38	22.86	28.52
Sunlight.....	2	1-2 B.Hol	301	2201.1	3.58	78.8	91.9	25.18	22.71	2.47
Starlight.....	2	1-2 B.Hol	334	5691.6	3.88	221.1	257.9	71.94	23.01	48.93
Average of all cows.....	5.6		297	4472.0	3.73	167.9	194.0	53.85	23.39	30.45

CABLE XXXIX.—HERD OF KROEGER BROS., RECORD OF PRODUCTION FOR YEAR 1912.

Blossom.....	3	1-2 B.Hol	365	4255.7	4.41	189.1	220.6	64.20	25.88	38.32
Pieterdje DeKol Mechthilde.....	7	PB Hol	282	7834.1	3.10	242.9	283.3	84.53	26.18	58.40

Junette Madrigal	7	PB Hol	304	6096.9	3 71	236.4	275.8	82.03	26.18	56.85
Countess Elgin Belle Pet.	4	PB Hol	7243.4	240.0	3 31	280.0	280.0	80.74	26.18	58.56
Antelope	4	1-2 B.Hol	290	4090.1	3 57	142.8	166.6	49.15	26.18	22.97
Flory	4	1-2 B.Hol	290	5927.0	3 54	210.2	246.2	66.44	24.26	42.18
Nellie	3	1-2 B.Hol	284	4459.7	3 63	162.1	189.1	57.63	26.18	31.45
Princess	3	3-4 B.Hol	327	4754.7	3 68	170.4	198.8	57.75	26.18	31.57
Queen	4	1-2 B.Hol	268	8474.0	4 06	141.1	164.6	47.71	24.61	23.10
Peterlje Dakota Mechthilde	5	PB Hol	304	6270.9	3 56	223.4	260.6	70.43	24.61	45.82
Blackie	5	1-2 B.Hol	282	4046.1	3 48	141.1	164.7	42.20	23.65	18.55
Fernie	4	1-2 B.Hol	271	5649.8	3 55	200.9	234.3	61.31	25.57	35.74
Whity	5	1-2 B.Hol	304	4007.4	3 76	161.0	176.1	52.07	25.57	26.50
Fanny	6	1-2 B.Hol	319	4863.8	3 86	187.7	218.9	60.03	23.75	36.28
Pet	3	1-2 B.Hol	315	4334.8	4 18	181.2	211.4	58.41	24.75	33.66
Duchess	4	1-2 B.Hol	262	4385.0	4 07	178.6	208.3	55.95	22.79	33.16
North Star Inka	5	PB Hol	214	4367.8	3 42	149.4	174.3	47.60	13.20	34.40
Average of all cows	4.7		296	5056.5	3 69	185.1	216.0	61.07	24.45	36.61

TABLE XL.—HERD OF FRED MICHEALS, RECORD PRODUCTION FOR YEAR 1912.

Jessie	4	Native	297	6122.0	4 09	250.6	292.3	84.75	27.80	56.95
Pauline Clothilde Posch	3	PB Hol	301	6536.5	3 06	200.0	233.3	67.99	27.80	40.19
Bessie	4	1-2 B.Hol	318	5778.6		211.1	246.2	70.98	27.80	43.18
Ruth	3	1-2 B.Hol	316	4901.8	3 58	175.4	204.6	58.35	27.80	30.55
Florence	3	1-2 B.Hol	277	4801.6	3 73	179.1	208.9	56.83	25.37	31.46
Queen	4	1-2 B.Hol	316	7141.8	3 67	260.8	304.2	87.75	29.80	57.95
Star	4	1-2 B.Hol	330	7747.7	3 46	268.0	312.6	90.54	27.80	62.74
Daisy	4	1-2 B.Hol	304	5437.4	3 84	209.3	234.1	65.90	24.80	41.10
Cordova Barbetta DeKol	8	PB Hol	298	9057.5	3 15	287.9	335.8	98.22	27.80	70.42
Barbetta Dakota DeKol	4	PB Hol	304	5959.4	3 28	195.8	228.4	66.81	27.80	39.01
Elsie	8	Native	294	3230.6	4 68	148.2	172.9	51.30	27.80	23.50
Grace	4	1-2 B.Hol	273	5063.8	3 47	176.7	206.1	54.06	21.44	32.62
Average of all cows	4.7		302	5981.5	3 62	213.5	248.2	71.12	26.98	44.13

TABLE XLI.—HERD OF WM. NEAS, RECORD OF PRODUCTION FOR YEAR 1912.

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Butter Fat	Butter	Value of Butter Fat	Total Cost of Feed	Profits
	YRS.		DAYS	LBS.	PR CT.	LBS.	LBS.	DOLS.	DOLS.	DOLS.
Pet.	15	Native	362	5806.9	8.41	198.1	231.1	64.61	85.16	29.45
Minnie.	7	Native	300	5616.1	3.66	205.6	239.8	60.86	23.72	82.14
Jessie.	3	Native	236	2958.4	3.71	109.7	127.9	33.84	27.35	6.49
Queen.	3	Native	225	2639.6	3.87	102.3	119.3	31.37	27.19	4.18
Bessie.	6	Native	319	6261.8	3.83	240.3	280.3	76.25	31.79	44.46
Nellie.	8	Native	282	6421.3	3.65	234.7	273.8	74.25	32.02	42.23
Darkie.	6	Native	265	4366.3	4.04	176.7	206.1	52.21	27.96	24.25
Dakota Pieterje Beryl	2	PB Hol	295	6682.0	3.46	231.4	289.9	68.46	25.17	43.29
Mollie.	4	Native	196	2770.8	3.40	94.3	110.0	29.64	25.02	4.62
Zerd.	4	Native	214	3967.8	3.61	153.2	148.7	46.39	25.02	21.37
Bob.	8	Native	290	5590.1	3.52	197.0	229.8	64.45	32.02	32.43
Star.	6	Native	147	2811.2	3.34	93.7	109.3	30.49	26.72	4.77
Beauty.	3	Native	232	3460.3	3.62	126.4	147.4	38.64	24.92	13.72
Average of all cows.	5.7		258	4565.5	3.62	166.4	191.8	51.65	28.31	23.33

TABLE XLII.—HERD OF ROBT. RUSCH, RECORD OF PRODUCTION FOR YEAR 1912.

Altoona Woodland Beryl	4	PH Hol	308	6454.8	3.48	225.0	282.2	65.49	27.66	37.83
Beauty 2nd	8	Native	298	4377.7	3.92	172.7	201.4	46.90	26.46	20.44
Bessie.	5	Native	328	4130.8	4.20	170.9	199.3	48.20	26.46	21.74
Crook-horn.	10	Native	276	3914.3	3.64	142.7	166.4	45.33	27.16	18.17
Mollie.	4	1-2 B. Hol	164	2633.8	3.82	100.8	117.6	30.17	11.86	18.31
English 2nd	8	Native	183	2404.0	4.46	97.3	115.5	25.35	16.21	9.14

Kicker	8	Native	304	4468.3	4.14	185.0	215.8	58.21	27.86	30.35
Lady	5	Native	302	4320.7	3.66	158.4	184.8	46.09	27.86	18.28
Florence	5	Native	294	3380.0	4.16	140.7	164.1	40.77	26.86	19.91
Nettie	10	Native	268	5798.3	3.68	213.4	248.9	67.74	27.86	39.88
Pet	12	Native	315	5729.2	4.02	230.4	269.0	70.18	27.16	43.02
Bud	5	Native	369	3271.6	4.88	127.2	149.8	85.55	13.86	21.69
Older	8	Native	365	5088.6	3.95	199.0	232.1	61.21	27.86	38.36
Average of all cows	7.0		290	4301.3	4.00	166.4	194.3	49.32	24.24	25.08

TABLE XLIII.—HERD OF DIET SCHWARTING, RECORD OF PRODUCTION FOR YEAR 1912.

Skylark Ormsby Heg DeKol	8	PB Hol	321	8530.3	3.58	306.1	357.1	95.61	30.78	64.83
Daisy Johanna Ormsby	7	PB Hol	228	6477.3	3.70	239.4	279.8	72.42	29.58	42.84
Shorty	10	Native	312	5224.2	4.54	229.6	267.8	78.10	29.58	48.52
White Face	4	1-2 B. Hol	321	4124.1	3.73	154.2	149.9	48.07	25.98	22.09
Lillie	8	Native	288	6173.1	3.63	224.6	262.0	71.98	25.98	46.00
Roete	9	Native	272	6594.4	3.67	241.9	282.2	82.44	29.58	52.86
Bobtail	10	Native	294	6177.9	3.78	254.0	296.3	85.71	29.58	56.13
Star	3	1-2 B. Hol	260	4080.8	3.57	146.1	170.4	43.63	25.53	18.10
Dakota Johanna Ormsby	3	PB Hol	269	5313.3	3.34	177.7	207.3	54.85	25.53	29.32
Dakota Ormsby DeKol	3	PB Hol	306	6476.0	3.12	202.1	235.7	65.84	27.48	38.36
Dakota Grace DeKol	3	PB Hol	292	4171.6	3.40	142.0	195.6	44.45	27.48	16.97
Dakota Colantha Queen	3	PB Hol	259	2935.5	3.64	107.0	124.8	32.77	15.30	17.47
Grace Ormsby DeKol	8	PB Hol	262	7759.0	3.47	269.4	314.3	81.37	27.38	53.99
Spottie	8	Native	290	5594.5	3.95	224.3	261.6	68.67	28.05	40.62
Brownie	6	Native	205	4172.0	3.97	165.3	192.8	49.96	26.53	24.43
Longfellow	3	1-2 B. Hol	303	5807.3	3.70	216.1	252.1	67.78	27.42	40.36
Queen Dakota Colantha	5	PB Hol	302	7808.1	3.41	266.4	310.8	83.38	27.18	56.15
Grace Dakota DeKol	5	PB Hol	285	6463.4	3.52	227.5	255.4	69.63	27.18	42.50
Queen	3	1-2 B. Hol	281	3712.0	4.46	165.8	173.4	57.84	28.06	28.06
Kicker	9	Native	182	3714.7	4.06	150.7	176.8	45.87	26.78	19.14
Black Beauty	5	1-2 B. Hol	365	7346.2	3.27	241.5	281.7	81.03	29.43	51.60
Average of all cows	5.8		280	5555.0	3.69	207.2	241.3	65.78	27.19	38.53

TABLE XLIV.—HERD OF HENRY TELLMAN, RECORD OF PRODUCTION FOR YEAR 1912.

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Etta Colanthus DeKol	5	PB Hol	312	6491.0	3.29	224.1	264.1	62.84	30.03	32.83
Topey		Native	330	4406.4	3.84	177.5	207.0	53.55	29.50	24.05
Whitehead	8	Native	289	4179.4	3.55	148.7	173.4	45.36	29.50	15.84
Buttercup	2	1-2 B.Hol	247	2492.2	3.41	85.1	99.2	23.10	14.90	8.20
H. K.	12	Native	300	3164.2	3.25	134.6	157.0	36.25	29.50	6.75
Slicky	9	Native	263	2938.6	3.80	116.8	136.2	37.67	28.80	8.87
Butter Maker		Native	288	3874.1	4.00	154.8	180.6	47.69	28.80	18.88
Brandt	7	Native	265	4324.4	3.80	164.6	192.0	47.81	27.10	20.71
Lue	7	Native	331	4222.9	4.14	175.0	204.1	50.60	27.67	23.93
Short-tail	8	Native	365	4514.4	4.41	199.3	232.5	60.12	28.80	31.82
Brown	10	Native	304	5027.0	3.90	196.9	229.7	52.59	26.67	25.92
Schimmel		Native	306	4504.4	3.94	177.8	207.4	49.07	25.67	23.40
Bruno	8	Native	217	3828.0	3.53	135.2	154.7	35.32	26.84	8.48
Spoty	11	Native	310	3756.0	4.09	163.4	178.9	46.45	28.80	17.65
Old Whitehead	10	Native	359	5573.0	3.81	212.7	248.1	62.16	28.80	33.36
H. B.	4	1-2 B.Hol	365	5309.6	4.27	226.8	264.6	63.38	28.80	34.58
Fanny	3	1-2 B.Hol	365	4455.0	3.72	166.0	193.6	47.63	28.54	19.09
Ball	3	1-2 B.Hol	310	4573.6	3.86	176.6	206.0	50.04	28.67	21.37
Average of all cows	7.1		307	4313.0	3.81	163.1	196.0	48.42	27.63	20.84

TABLE XLV.—HERD OF WM. TELLMAN, RECORD OF PRODUCTION FOR YEAR 1912.

	8	PB Hol	312	8609 3	3 32	286 3	334 0	89 41	80 20	69 21
Sally DeKol Ormsby.	4	PB Hol	298	5166 2	3 40	175 9	205 2	58 24	29 40	28 34
Rose Dakota Ormsby.	5	PB Hol	286	5195 8	3 34	173 7	202 6	55 16	29 40	26 76
Sally Dakota Ormsby.	4	1-2 B.Hol	300	5770 6	3 71	214 2	249 9	65 91	29 40	36 51
Helen.	5	1-2 B.Hol	197	5408 1	3 24	175 7	204 9	51 78	29 40	22 38
Whiteface.	4	1-2 B.Hol	386	7599 4	3 47	262 3	306 0	81 97	29 40	52 67
Blacky.	4	1-2 B.Hol	284	4601 8	3 75	172 6	201 3	56 25	29 10	27 15
Cherry.	4	1-2 B.Hol	174	2684 3	3 58	96 3	112 3	28 07	27 60	47
Bessie.	4	1-2 B.Hol	267	5167 3	3 78	195 8	227 3	61 08	27 60	38 38
Dora.	4	1-2 B.Hol	275	6090 8	3 66	228 3	260 5	69 77	27 90	41 87
Nance.	5	1-2 B.Hol	321	6588 6	3 62	238 4	278 1	74 53	27 30	47 23
Ida.	4	1-2 B.Hol	365	5932 3	3 97	235 4	274 6	76 72	29 40	47 32
Queen.	4	1-2 B.Hol	320	5666 1	3 83	217 5	253 7	72 02	30 20	41 82
Richy.	9	Native	261	5425 2	4 14	225 1	262 6	69 76	27 90	41 86
Nellie.	11	Native	276	3664 2	3 80	189 4	162 6	47 20	29 40	17 80
Butter.	12	Native	266	4771 4	3 75	179 2	209 0	59 43	27 90	31 53
Whitehead.	11	Native	264	3384 7	3 65	128 6	144 2	39 14	17 70	21 44
Fly.	3	1-2 B.Hol	265	3653 3	3 65	133 4	155 6	42 28	17 40	24 38
Canary Dakota Ormsby.	2	PB Hol	365	6086 3	3 66	222 8	259 9	70 94	28 20	42 74
Spottie.	10	Native	268	5323 0	3 55	89 2	220 7	54 65	28 50	26 15
Stella.	8	Native	223	3231 7	3 65	118 1	137 7	35 43	27 90	7 53
Hill.	4	1-2 B.Hol	335	5842 3	3 70	216 1	252 1	69 88	28 50	41 38
Jessie.	3	1-2 B.Hol	284	5266 2	3 64	186 9	228 4	60 43	27 71	32 71
Average of all cows.	5.8									

TABLE XLVI.
THE AVERAGE PRODUCTION OF EACH HERD
DURING THE YEAR 1912.

Owner of Herd	Average Age of cows	Number in Herd	Milk		Average Test	Fat	Butter	Value of Fat	Cost of Feed	Profits
	yrs.		lbs.	pr ct.	lbs.	lbs.	lbs.	dols.	dols.	dols.
Christiansen & Son.	5.0	10	6,164.8	3.32	205.5	239.7	66.16	32.23	33.92	
Gaebel, Frank.	6.3	17	5,304.3	3.66	189.5	221.2	61.97	26.52	35.45	
Holle, George.	4.0	7	5,422.1	3.86	204.5	238.7	63.29	26.84	36.45	
Holle, Henry W.	5.1	22	4,962.5	3.62	178.4	208.1	57.73	24.41	33.72	
Klusman, Chas., Sr.	4.2	19	4,510.2	3.67	165.9	193.5	53.08	22.43	30.64	
Klusman, John	5.6	16	4,472.0	3.73	167.9	194.0	53.85	23.39	30.45	
Kroeger Bros.	4.7	17	5,055.5	3.69	185.1	216.2	61.07	24.45	36.61	
Micheals, Fred.	4.7	12	5,981.5	3.62	213.5	248.2	71.12	26.98	44.13	
Neas, Wm.	5.7	13	4,565.5	3.62	166.4	191.8	51.65	28.31	23.33	
Rusch, Robt.	7.0	13	4,301.3	4.00	166.4	194.3	49.32	24.24	25.08	
Schwartz, Diet.	5.8	21	5,655.0	3.69	207.2	241.3	65.78	27.19	38.58	
Tellman, Henry.	7.1	18	4,313.0	3.81	168.1	196.0	48.42	27.63	20.84	
Tellman, Wm.	5.8	22	5,266.2	3.64	186.9	223.4	60.43	27.71	32.71	
Average.	5.5	207	5,031.2	*3.69	183.6	214.3	58.38	26.08	32.84	

†Three missing. *One missing.

**TABLE XLVII SHOWING THE AVERAGE DAILY
RATION FED TO THE COWS IN THE CIRCUIT DURING
THE MONTH OF JANUARY 1912.**

Owner of Herd	Millet Hay	Prairie Hay	Silage	Wheat Straw	Corn Stover	Oat Hay	Flax
Henry Holle	14.51		33.87		53.22	8.70	
John Christiansen & Son	22.58		35.00	6.45			
Chas. Klusman	30.83						
Wm. Tellman	16.12			12.90	12.90		
Robt. Rusch	11.60	11.60			6.77		
John Klusmann	23.22				8.06		
Frank Gaebe	16.00		35.00				
Wm. Neas	22.17	11.93	32.74	12.90	14.51		
Wm. Tellman	23.22						
Kroeger Bros.	7.74		30.61				9.67
Fred Micheals	6.45					6.45	
George Holle	21.14					19.35	
Diet Schwarting	12.90			12.90	14.51		

TABLE XLVIII.—HERD OF JOHN CHRISTIANSEN, RECORD OF PRODUCTION FOR YEAR 1913.

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yrs.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Dakota Paul DeKol.	4	PB Hol	315	8225.7	3.25	265.5	318.6	93.55	36.95	55.60
Beauty 2nd		1-2 B.Hol	317	8771.7	3.12	274.0	328.8	96.62	36.97	37.65
Aaggie Belle Vokolina.	7	PB Hol	319	6749.3	3.62	237.7	285.24	83.67	36.99	45.98
De Vries Hengerveld DeKol.	10	PB Hol	333	8824.3	3.27	289.0	346.80	98.34	36.20	62.54
Butterine Gem DeKol	10	PB Hol	101	1212.3	3.85	45.9	55.08	18.43	28.62	
Pleasant Gro ve Maid	2	PB Hol	276	5766.2	3.23	186.6	223.92	56.85	20.80	36.05
Flossie.		1-2 B.Hol	363	5996.9	3.28	196.7	236.04	65.92	36.73	29.19
Sally.	3	3-4 B.Hol	365	5996.9	3.21	192.8	231.36	64.44	36.73	27.71
Pearl.	4	Gr Hol	338	5775.3	3.39	196.2	235.44	66.35	36.73	28.62
Princess Dakota DeKol	6	PB Hol	340	7754.2	3.58	271.5	325.80	89.15	36.73	52.42
Pleasant Grove Princess.	2	PB Hol	282	4974.0	3.18	159.1	190.92	49.91	24.40	26.21
Mary.	4	1-2 B.Hol	287	6388.0	3.63	232.8	281.36	74.20	36.23	37.97
Roamy.		1-2 B.Hol	303	7589.9	3.54	268.0	321.60	94.31	37.11	57.20
Blackie.	5	1-2 B.Hol	305	7023.9	3.56	250.4	300.48	91.58	37.11	54.47
Nancy.	5	1-2 B.Hol	299	6581.3	3.48	229.4	275.28	71.63	25.53	46.10
Pet 2nd.	5	1-2 B.Hol	332	5961.8	3.73	222.0	267.48	75.63	38.73	38.90
Freahy.	3		332	6466.9	3.68	237.7	285.24	78.26	33.75	42.81
Bogby.	3	1-2 B.Hol	320	8027.4	3.41	274.1	328.92	96.78	37.11	58.67
Fanny.	3	1-2 B.Hol	343	5682.3	3.53	201.1	241.32	68.90	37.11	32.29
Average of all cows.	4.7		309	6514.12	3.44	222.65	267.35	75.44	34.13	42.77

TABLE XLIX.—HERD OF WM. NEAS, RECORD OF PRODUCTION FOR YEAR 1913.

Lacy.	2	1-2 B.Hol	245	2651.9	3.81	98.7	118.44	29.13	12.53	16.60
Pet.	17	Native	334	4556.7	3.86	176.4	211.68	63.61	36.08	28.58
Minnie.	10	Native	306	6361.2	3.41	217.4	260.88	69.40	31.45	37.95

Jessie	6	Native	304	4197.0	3.86	159.9	191.88	48.98	25.65	23.33
Queen	6	Native	274	3606.0	4.04	146.9	175.08	50.92	32.05	18.87
Boatie	10	Native	261	5866.3	3.66	216.6	259.92	72.51	38.29	34.22
Nellie	12	Native	243	5819.0	3.89	197.2	236.64	68.86	38.29	30.07
Ollie	2	1-2 B.Hol	275	2991.6	3.79	113.4	136.08	33.94	16.65	17.29
Darlie	9	Native	245	3184.5	3.64	116.1	139.32	36.62	15.45	21.17
Dakota Piertertje Beryl	4	PB Hol	318	6729.2	3.34	224.7	269.64	72.15	35.05	37.10
Mollie	6	Native	334	3813.5	3.88	149.4	179.28	49.81	33.65	16.16
Zera	7	Native	257	3639.7	4.15	146.8	176.16	47.24	26.40	20.84
Bob	11	Native	326	6148.5	3.70	227.6	273.12	79.50	39.69	39.81
Star	7	Native	230	3461.3	3.81	85.3	102.36	22.30	19.90	9.40
Average of all cows	7		282	4501.8	3.73	162.5	195.03	53.17	28.64	25.09

TABLE L.—HERD OF JOHN KLUSMANN, RECORD OF PRODUCTION FOR YEAR 1913.

Brownie	10	Native	306	3363.5	3.8	126.3	151.56	29.15	27.00	5.59
Bobtail	11	Native	365	3614.1	3.90	154.5	185.40	39.78	29.00	13.78
Bessie	6	1-2 B.Hol	120	591.1	3.80	20.7	24.84	4.99	24.00	
Bird	5	1-2 B.Hol	320	510.5	3.41	174.4	209.28	53.73	37.00	16.73
Moontight 2 nd	3	1-2 B.Hol	335	5618.5	3.62	203.3	243.96	62.95	37.50	25.65
Marble	11	Native	365	5604.5	3.26	196.8	236.16	51.10	30.00	24.10
May	6	1-2 B.Hol	306	5515.7	3.24	211.3	252.56	65.41	37.50	27.91
Star 2nd	6	3-4 B.Hol	337	4587.6	3.64	167.0	200.40	53.93	35.00	18.93
Rosie	6	1-2 B.Hol	315	6906.2	3.58	247.2	296.64	80.94	36.72	44.22
Shorthorn	10	Native	334	3998.1	2.75	136.3	163.56	35.66	27.50	11.16
Wheely	5	1-2 B.Hol	306	7517.4	3.37	253.5	304.20	79.61	36.00	43.61
Belle	5	1-2 B.Hol	309	6676.1	3.53	236.0	283.20	73.83	37.50	36.33
Bloome	5	1-2 B.Hol	304	6261.8	3.29	206.5	247.80	68.51	36.70	31.81
Sun Light	4	1-2 B.Hol	306	5947.5	3.58	213.0	255.60	67.88	36.00	35.61
Star Light	4	1-2 B.Hol	305	5360.0	3.83	224.5	269.40	72.25	36.00	36.23
Skylark Dakota Hengerveld	3	PB Hol	304	4074.3	3.53	144.1	172.92	46.91	35.85	11.26
Dakota Piertertje Snowflake	3	PB Hol	304	4032.9	3.43	138.4	166.08	46.19	35.25	9.95
Average of all cows	6		308	4804.69	3.50	179.62	215.50	54.87	33.79	24.55

TABLE LI.—HERD OF WM. TELLMAN.—RECORD OF PRODUCTION FOR YEAR 1913.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat dols.	Total Cost of Feed dols.	Profits dols.
Sally DeKol Ormsby	9	PB Hol	263	7256.1	3.38	245.9	295.08	75.67	35.93	39.74
Rose Dakota Ormsby	5	PB Hol	288	4838.4	3.57	162.5	195.00	48.52	33.45	16.37
Sally Dakota Ormsby	6	PB Hol	273	5683.9	3.59	203.5	244.20	67.38	37.33	30.20
Canary Dakota Ormsby	2	PB Hol	322	5547.9	3.47	192.4	230.88	59.13	36.95	22.18
Dakota of Stillwater	2	PB Hol	285	6302.1	3.27	206.1	247.32	63.29	34.43	28.86
Dora Dakota Ormsby	2	PB Hol	334	6278.4	3.36	210.9	253.08	68.60	37.43	31.17
Dakota DeKol Ormsby	2	PB Hol	214	3693.4	3.45	127.5	153.00	38.13	33.45	5.08
Dakota Gem DeKol	3	PB Hol	275	4260.1	3.41	145.5	174.60	45.12	33.91	11.09
Sally Dakota Ormsby	2	PB Hol	178	2897.2	3.58	104.1	240.08	32.43	35.63	— 60
Helen	5	1-2 B Hol	278	6403.4	3.59	230.0	276.00	70.95	35.83	35.12
Whiteface	6	1-2 B Hol	303	7761.8	3.54	272.0	277.44	86.47	36.28	50.24
Blacky	5	1-2 B Hol	330	7815.2	3.61	282.5	339.00	87.34	35.33	51.51
Cherry	5	1-2 B Hol	241	3661.2	3.80	144.0	172.80	49.11	31.95	17.16
Dora	5	1-2 B Hol	298	5334.2	3.57	190.4	228.48	56.92	32.73	21.89
Neance	5	1-2 B Hol	294	7122.5	3.72	263.7	316.44	80.76	32.73	47.83
Ida	6	1-2 B Hol	355	8665.1	3.35	294.4	353.28	92.82	34.23	58.09
Queen	7	1-2 B Hol	172	2966.8	3.67	109.1	130.92	35.98	29.75	6.03
Hill	5	3-4 B Hol	235	4675.4	3.53	165.5	198.60	51.55	33.45	17.60
Jessie	4	1-2 B Hol	215	4962.7	3.50	173.6	208.32	62.61	32.45	30.06
Average of all cows	4.5		271	5570.3	3.52	195.97	238.65	61.72	34.37	27.29

TABLE LII.—HERD OF DIET SCHWARTING, RECORD OF PRODUCTION FOR YEAR 1913.

Slylark Ormsby DeKol Hengerveld	9	PB Hol	334	7706.1	3.50	270.4	324.48	86.07	40.79	45.28
Daisy Johanna Ormsby	8	PB Hol	304	7667.9	3.55	272.3	236.76	92.83	40.89	51.94
Shorty	11	Native	274	3950.7	3.80	141.4	169.68	48.92	36.32	12.60

White Face	5	1-2 B.Hol	335	6291	1	3	44	217	1	260	52	72	85	39	09	33	76
Lilile	9	Native	304	4295	9	3	83	166	6	199	92	55	56	36	12	19	44
Rosie	10	Native	274	5121	3	3	50	180	1	216	12	62	23	39	09	28	14
Bobtail	11	Native	304	3861	4	4	17	160	9	193	08	51	29	36	05	15	24
Star	4	1-2 B.Hol	274	4454	7	3	37	150	9	181	08	48	29	36	23	10	06
Dakota Johanna Ormsby	4	PB Hol	304	7198	6	3	21	231	6	277	92	80	06	40	63	39	48
Dakota Ormsby DeKol	3	PB Hol	304	4947	9	3	23	149	8	179	76	49	42	38	13	11	29
Dakota Grace DeKol	3	PB Hol	214	4284	1	3	14	134	8	161	76	40	79	34	93	5	86
Dakota Colantha Queen	3	PB Hol	245	4280	3	3	73	159	1	190	93	47	88	33	45	14	43
Grace Ormsby DeKol	9	PB Hol	304	8258	9	3	35	277	1	332	53	91	73	38	87	52	86
Spottie	9	Native	273	3904	6	3	70	144	5	173	40	43	48	35	74	7	74
Brownie	7	Native	107	4231	3	4	08	173	1	207	72	52	44	37	11	19	94
Longfellow	4	1-2 B.Hol	304	6798	4	3	65	211	9	254	28	65	03	36	57	28	46
Queen Dakota Colantha	6	PB Hol	334	6708	3	3	37	226	1	271	32	74	98	39	86	35	12
Queen Dakota DeKol	6	PB Hol	301	6324	5	3	50	221	5	265	80	74	39	37	11	37	28
Queen	4	1-2 B.Hol	332	6153	1	4	09	251	2	301	44	86	91	36	79	50	12
Daisy Johanna Ormsby	3	PB Hol	334	4805	0	3	48	167	7	201	24	54	91	37	11	17	80
Black Beauty	6	1-2 B.Hol	337	7352	0	3	20	235	3	282	36	78	58	38	17	40	41
Average of all cows	6		289	5599	8	3	56	197	3	234	67	64	67	37	64	27	24

TABLE LIII.—HERD OF KROEGER BROS., RECORD OF PRODUCTION FOR YEAR 1913.

Blossom	4	1-2 B.Hol	341	5119	6	4	23	216	9	260	28	74	89	34	38	40	51
Pietertje DeKol Mechthilde	8	PB Hol	324	9099	4	3	25	297	8	357	36	98	23	35	14	63	09
Junette Magrigr	8	PB Hol	300	8552	6	3	39	290	3	348	36	103	66	35	14	67	52
Countess Eigin Belle Pet.	9	PB Hol	291	7830	1	3	52	276	2	331	44	88	81	33	34	56	47
Antelope	5	1-2 B.Hol	331	6498	8	4	22	274	5	329	40	91	60	34	48	57	12
Princess	4	3-4 B.Hol	191	3031	1	3	95	121	8	146	16	42	07	24	34	20	83
Dakota Junette Kaan	2	PB Hol	325	6981	3	3	80	265	8	318	96	86	29	34	78	51	51
Rosie	5	1-2 B.Hol	327	7043	5	3	72	262	2	314	64	83	48	34	48	49	00
Pietertje Dakota Mechthilde	6	PB Hol	335	7796	0	3	55	277	4	332	88	84	73	34	34	50	39
Fernie	5	1-2 B.Hol	302	7585	4	3	56	270	4	324	48	84	54	34	08	50	46
Pet.	4	1-2 B.Hol	337	7008	5	4	30	301	4	361	68	103	66	34	38	69	28
Duchess	5	1-2 B.Hol	202	2741	6	4	20	114	2	137	04	38	83	84	38	12	81
North Star Inka	5	PB Hol	308	7088	3	3	53	250	7	300	84	78	32	35	14	43	18
Pride Pietertje Dakota	3	PB Hol	307	4987	2	3	84	191	7	230	04	64	89	35	14	29	75

Name of Cow	Age	Breed	Milking during year	Milk	Average Test	Fat	Butter	Value of Fat	Total Cost of Feed	Profits
	yr.		days	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
Dakota Mechthilde	3	PB Hol	319	6757.7	3.24	218.1	261.72	82.21	34.84	47.37
Pietertje DeKol Mechthilde	1	PB Hol	317	4916.2	3.94	192.8	231.26	61.80	33.24	28.56
Pietertje Dakota Mechthilde	2	PB Hol	316	5888.3	3.80	222.1	266.52	71.82	28.84	42.98
Average of all cows	4.6		304	6404.4	3.76	237.9	285.48	78.81	33.55	45.87

TABLE LIV.—HERD OF CHAS. KLUSMAN, SR., RECORD OF PRODUCTION FOR YEAR 1913.

Rosie	6	1-2 B.Hol	284	6300.8	4.35	274.5	329.40	79.79	38.29	41.41
Grace	5	1-2 B.Hol	365	6916.5	4.06	280.6	336.72	89.94	38.29	51.65
Blackie	4	1-2 B.Hol	304	6272.1	3.84	240.8	288.96	80.77	36.64	45.13
Minnie	5	1-2 H.Bol	311	7268.8	3.53	254.7	305.64	80.02	34.69	44.48
Alma Marie 6th	9	PB Hol	289	599.0	3.86	232.1	278.52	69.89	37.19	32.70
Dakota of Elmwood		PB Hol	334	7194.3	3.43	247.0	296.40	79.10	38.19	40.01
Mable	4	1-2 B.Hol	334	5847.7	3.53	206.7	248.04	66.70	35.69	31.01
Emma	4	1-2 B.Hol	245	4060.8	3.51	142.8	171.36	42.42	16.19	26.23
Scrub	9	1-2 B.Hol	289	6959.2	3.47	241.9	290.28	76.47	34.19	41.18
Elsie	3	1-2 B.Hol	313	4796.2	3.81	183.0	219.60	58.12	34.69	23.48
Lillie	5	1-2 B.Hol	355	7637.4	3.37	257.8	309.36	85.26	37.19	48.07
Baldface	3	1-2 B.Hol	310	4654.1	3.59	167.0	200.40	52.51	33.69	19.12
Whitehead	5	1-2 B.Hol	273	5361.5	3.42	183.8	220.56	59.05	34.99	24.06
Pink	4	1-2 B.Hol	231	3918.5	3.31	129.7	155.64	44.67	35.79	8.88
Gray	5	1-2 B.Hol	334	7598.2	3.56	271.2	325.44	90.31	37.19	53.12
Maud	2	3-4 B.Hol	325	5021.0	3.89	195.3	234.36	62.93	36.19	26.74
No. 24			306	2725.8	3.98	108.8	230.56	34.84	32.09	8.15
Average of all cows	4.6		300	5795.9	3.67	212.8	261.24	67.75	34.77	32.96

TABLE LV. — HERD OF FRED MICHEALS, RECORD OF PRODUCTION FOR YEAR 1913.

Jessie.	5	Native	305	6912.8	4.14	286.2	343.44	100.46	85.76	64.70
Pauline Clothilde Posch.	4	PB Hol	304	8223.2	3.08	254.0	304.80	90.98	37.84	53.14
Beasle.	5	1-2 B.Hol	335	6846.4	3.30	216.2	259.44	75.14	36.11	39.03
Ruth.	4	1-2 B.Hol	324	6307.7	3.46	218.8	262.56	75.65	36.11	39.84
Florence.	4	1-2 B.Hol	361	7417.0	3.56	266.7	320.04	89.16	34.06	55.10
Queen.	5	1-2 B.Hol	283	7478.0	3.34	250.0	300.00	86.62	38.23	48.49
Pauline Clothilde Posch 2nd	2	PB Hol	300	7409.5	3.41	263.1	338.72	80.19	29.26	50.93
Cordova Barbetta DeKol.	9	PB Hol	342	8867.0	3.16	230.8	336.96	98.34	38.19	60.15
Grace.	5	1-2 B.Hol	301	5397.4	3.43	202.5	243.00	66.09	33.46	32.63
Barbetta Dakota DeKol.	5	PB Hol	335	8008.1	3.10	248.5	298.20	86.46	37.47	48.99
Daisy.	5	1-2 B.Hol	273	6340.8	3.55	225.5	270.60	74.73	32.01	42.32
No 8.	2	PB Hol	245	4923.9	3.41	167.9	201.48	49.40	20.41	28.99
Average of all cows.	4		309	7027.65	3.41	239.1	287.02	81.10	34.07	47.00

TABLE LVI.—HERD OF FRANK GAEBE, RECORD OF PRODUCTION FOR YEAR 1913.

Pearl.	7	1-2 B.Hol	334	6403.8	3.95	253.1	203.72	89.32	46.45	42.87
North Star Salo.	4	PB Hol	305	3119.1	3.41	106.5	127.80	31.39	24.42	5.77
White.	11	Native	365	4030.6	4.00	142.1	170.52	44.89	35.65	13.24
Spottie.	6	1-2 B.Hol	291	6183.6	3.33	236.9	294.28	83.96	44.44	39.62
Johanna DeKol Posch.	5	PB Hol	326	9600.7	3.24	311.8	274.16	109.87	50.40	59.47
Indi Pense Surprise.	3	PB Hol	336	1175.8	2.98	333.8	400.56	117.18	50.40	66.78
Indi Aattje Surprise.	6	PB Hol	339	5149.8	3.59	184.9	221.88	62.29	47.11	16.18
Star.	5	1-2 B.Hol	320	5647.2	3.40	192.1	230.52	63.49	42.17	21.32
Blue.	6	1-2 B.Hol	365	2737.3	3.59	100.0	120.00	30.30	15.95	14.35
Queen.	6	1-2 B.Hol	314	7973.5	3.54	282.8	339.36	99.12	50.70	48.42
Flippin.	7	1-2 B.Hol	231	4292.3	4.07	174.9	209.88	64.62	40.54	23.08
Fly.	6	2-4 B.Hol	314	6355.7	3.59	228.3	273.96	71.33	33.58	38.53
Boss.	7	1-2 B.Hol	317	6406.7	3.74	240.2	288.24	83.89	47.27	36.62
Marry.	6	1-2 B.Hol	284	7528.2	3.56	268.1	321.72	93.59	44.74	48.35
Johanna DeKol Posch.	2	PB Hol	291	6732.0	3.50	237.4	284.88	75.86	34.84	40.26
Alcartra.	2	PB Hol	125	2387.4	3.77	89.9	107.88	30.49	16.32	15.17
Average of all cows.	5.5		303	5364.35	3.61	211.4	241.83	71.97	38.99	33.09

TABLE LVII.—HERD OF HENRY W. HOLLE, RECORD OF PRODUCTION FOR YEAR 1913.

Name of Cow	Age	Breed	Milking during year	Milk lbs.	Average Test pr ct.	Fat lbs.	Butter lbs.	Value of Fat dols.	Total Cost of Feed dols.	Profits dols.
Kaan Marie of Dakota	4	PB Hol	334	8183.7	3.12	255.7	276.84	86.02	42.82	43.20
Fanny	6	1-2 B.Hol	304	6861.3	3.41	233.9	280.68	72.38	32.35	40.03
Rosie	5	1-2 B.Hol	296	5358.9	3.20	171.6	205.92	61.98	32.05	19.85
Lilly	6	1-2 B.Hol	306	5759.5	3.66	211.0	233.20	65.83	29.45	36.88
Sally	3	1-2 B.Hol	318	5783.7	3.38	195.5	234.60	64.56	36.85	27.71
Dakota Marie Kaan	4	PB Hol	304	6359.8	3.36	220.7	264.80	70.92	38.73	32.09
Kaan Marie of Edgetown	10	PB Hol	334	8280.3	3.37	279.6	335.52	91.54	40.83	50.72
Daisy	7	1-2 B.Hol	334	6909.3	3.53	245.5	294.60	77.62	34.93	42.69
Dora	7	1-2 B.Hol	317	8814.9	3.46	283.4	340.08	96.09	41.83	54.26
North Star Bess	5	PB Hol	336	5847.6	2.97	173.6	208.32	54.55	33.23	21.82
Stickie	6	1-2 B.Hol	334	7708.0	3.69	284.1	340.92	88.58	35.43	53.15
Blue Belle	3	3-4 B.Hol	303	4786.8	3.31	158.7	190.44	48.64	33.17	15.47
Bessie	4	1-2 B.Hol	245	4916.3	3.62	178.1	213.72	52.88	28.13	24.75
Tressie	5	1-2 B.Hol	304	6616.5	3.66	244.6	293.52	80.57	39.23	41.34
Spottie	4	1-2 B.Hol	303	4211.6	3.53	148.7	178.44	49.95	32.23	17.92
Average of all cows	5		311	6426.54	3.41	218.98	260.77	70.14	35.41	34.72

TABLE LVIII.—HERD OF GEO. HOLLE, RECORD OF PRODUCTION FOR YEAR 1913.

Beauty	2	1-2 B.Hol	325	4108.5	3.81	156.8	188.60	55.19	36.32	16.67
Daisy Ormsby Johanna	8	PB Hol	315	6768.3	3.62	245.1	294.12	75.56	35.86	39.80
Flip	4	1-2 B.Hol	246	6450.7	3.35	216.6	259.92	66.80	32.00	34.80
Kaan Jewel Canary Mechthilde	8	PB Hol	365	7931.4	3.71	294.4	363.28	96.70	38.52	58.18
Star	4	Native	318	5773.1	3.84	222.0	266.40	75.03	38.52	36.51
Jessie	4	1-2 B.Hol	256	5041.0	3.65	184.0	220.80	65.00	36.52	28.48
Glenview Johanna Ormsby	3	PB Hol	283	3390.2	4.17	141.6	169.92	43.92	33.62	10.40
Pet	3	1-2 B.Hol	365	5010.9	3.75	188.0	225.60	60.82	36.52	24.40
Jessie	4	1-2 B.Hol	300	6438.4	3.67	236.3	283.56	80.25	39.40	39.85
Average of all cows	4.4		306	5656.9	3.73	209.4	251.35	68.80	36.36	32.12

TABLE LIX. THE AVERAGE PRODUCTION OF EACH HERD, DURING THE YEAR 1913.

Owner of Herd	Average Age of cows	Number in Herd	Milk	Average Test	Fat	Butter Value of	Fat	Cost of Feed	Profit
			lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
George Hoile	4.4	9	5656.90	3.73	209.40	251.35	68.80	86.86	82.12
Fred Michenls.	4.5	12	7027.65	3.41	239.10	287.02	81.10	84.07	47.00
Frank Gaeb.	5.5	16	5364.85	3.61	211.42	241.83	71.97	88.99	38.09
Chas. Klusman, Sr.	4.9	17	6796.90	3.67	212.80	261.24	67.76	84.77	32.96
Kroeger Bros.	4.8	17	6404.44	3.76	237.90	285.48	78.81	83.55	45.87
Jno. Klusmann	6.0	17	4804.69	3.50	179.62	215.50	54.87	83.79	24.55
Diet Schwarting	6.3	21	5699.81	3.56	197.30	234.67	64.67	87.64	27.24
Wm. Neas	7.7	14	4501.80	3.73	162.50	195.08	53.17	28.64	26.09
Wm. Tellman	4.5	19	5570.30	3.52	195.97	238.65	61.72	84.37	27.29
Henry W. Holle	5.2	15	6426.54	3.41	218.98	260.77	70.14	85.41	34.72
John Christiansen	4.7	19	6514.12	3.44	222.65	267.35	75.44	84.13	42.77
Average	5.3	176	5778.33	3.57	207.44	248.39	67.78	84.76	133.62

*Three Missing. †Two missing.

**TABLE LX SHOWING THE AVERAGE DAILY RATION
FED TO THE COWS IN THE CIRCUIT DURING THE
MONTH OF JANUARY 1913**

Owner of Herd	Millet Hay	Prairie Hay	Oats	Corn Stover	Silage	Barley and Oats
Chas. Micheals	12.32	6.12			18.05	4.51
Chas. Klusman, Sr.	16.12	9.67		12.90		3.12
Wm. Tellman	19.35	9.67	2.07	12.90		
Jno. Christiansen	14.83	14.83	5.48		30.00	
Frank Gaebe	19.35	9.67		9.67	35.00	6.41
George Holle	19.35	9.67		12.90		
Diet Schwarting	18.52	9.67	6.64			
Kroeger Bros.		12.32	4.76		36.00	
Jno. Klusmann	19.35	9.67	4.83	12.90		
Henry W. Holle	14.00	8.00	8.91		38.70	
Wm. Neas	22.58	6.45	3.22		35.48	

**TABLE LXI SHOWING A COMPARISON OF THE AVERAGE OF THE
RESULTS PER COW PRODUCED BY ALL THE HERDS IN THE
CIRCUIT FOR THE YEARS 1910, 1911, 1912 AND 1913.**

Year	Average age of cows	Milk yield	Average Test	Fat	Butter	Value of Fat	Cost of Feed	Profit
	yrs.	lbs.	pr ct.	lbs.	lbs.	dols.	dols.	dols.
1910	5.8	4634.9	3.89	180.3	210.2	60.24	29.46	30.83
1911	5.6	5106.2	3.76	191.8	223.9	52.85	29.00	24.31
1912	5.5	5031.2	3.69	183.6	214.3	58.38	26.08	32.34
1913	5.3	5778.3	3.57	207.4	248.3	67.78	34.76	33.62
Average	5.5	5137.6	3.72	190.7	224.1	59.81	29.82	30.21

TABLE LXII.—LIST OF COWS PLACED IN THE ADVANCED REGISTRY ON THE 7 DAY TEST.
PRIOR TO AUG. 1ST, 1913.

Name of cow and Reg. No.	Sire	Dam	Age at time of record			7 Day Record			Owner
			Yrs.	Mo.	Days	Lbs.	Milk	Pr ct.		Lbs.	Fat
Barbetta Dak. Ormsby 206152	Hengerveld Ormsby DeKol 41085	Cordora Barb. DeKol 78689	3	10	21	276.2	3.44	9.50	Fred Michaels
Beryl Lilith Pieterie 115646	Lilith Pauline DeKol Beryl 53678	Irmuna Pieterie DeKol 76485	3	4	14	364.4	3.19	10.96	Wm. Neas
Bodora Max. DeKol 104373	Maximum DeKol 39563	Bodora Wayne DeKol 3d 109377	3	4	14	265.9	4.03	10.31	Morris Tausend
Dakota of Elmwood 139155	Dora Sir Gem 39563	Alma Marie 6th Daughter 783257	1	11	27	292.1	4.12	12.03	Chas. Klusman, Sr.
Dakota Paul. DeKol 123400	Sir Wit Mercedes 40704	Maid Paul. De Kol 78920	2	11	3	296.9	3.09	9.20	John Christiansen
Dakota Pieterie Beryl 137813	Count Freeman of Granville 51873	Beryl Lilith Pieterie 112390	2	0	18	279.8	3.11	8.98	Wm. Neas
Elmwood Princess Dakota 181857	Dora Sir Gem 39563	Alma Marie 6th Daughter 183257	2	1	27	266.6	3.76	10.36	Chas. Klusman, Sr.
Johanna DeKol Posch 2d 164108	Sir Dakota Mercedes 53424	Johanna DeKol Posch 120219	2	3	11	265.7	3.10	8.26	Frank Gaabe
Pauline Clothilde Posch 2d 181838	Hengerveld Ormsby DeKol 41085	Pauline Clothilde Posch 120218	2	3	11	315.6	3.45	11.01	Frank Michaels
Princess Dakota DeKol 107482	Sir Wit Mercedes 4-704	Maid Paul DeKol 78920	2	11	4	266.8	3.44	9.22	John Christiansen
Pleasant Grove Maid 156459	Sir Dakota Mercedes 53424	Princess Dakota DeKol 107482	2	11	4	261.9	2.98	7.84	John Christiansen
Pleasant Grove Princess 156456	Sir Dakota Mercedes 53424	De Vries Hengerveld DeKol 73330				264.6	2.78	7.39	John Christiansen

TABLE LXIII. LIST OF HERD SIRES IN THE CIRCUIT DURING 1913

Name of Bull	Date of Birth	Name of Sire	Name of Dam	Name of Owner
Colanuths Johanna Beets 65136	Oct. 9, 1909	Laurel Lodge Duke 41309	Catrina Korndyke Beets 84952	John Christiansen
Count Dakota of Pleasant Valley 96758	Oct. 15, 1911	Sir Dakota Ormsby 69166	Countess Elgin Belle Pet 75254	Frank Gaeb
Dakota Kaan 53426	Feb. 4, 1908	Kaan Clothilde Duke 32069	Countess Elgin Belle Pet 57254	Robert Ruch
Hengerveld Ormsby DeKol 41085	July 12, 1905	Sir Ormsby Hengerveld DeKol 31212	Grace P. DeKol 62233	Chas. Klusman
Kaan Dakota Duke 65590	Apr. 13, 1909	Dakota Duke Kaan 45084	Beryl Lilith Pieterie 112390	John Tellman
Pieterie Dakota Beryl 96087	Jan. 21, 1911	Dakota Duke Clothilde 46085	Bodora Maximum DeKol 104373	George Holle
Piebe Belle Burke 99210		Piebe Belle Burke 63344	Junette Madrigal 77992	Wm. Neas
Sir Colantha Dakota 96758	Oct. 10, 1911	Sir Dakota Ormsby 69166	Norma Catherine Dakota 109287	Henry W. Holle
Sir Dakota Elmwood 97184	Oct. 27, 1910	Dora Sir Gem 39563	Sally DeKol Ormsby 75996	Diet Schwarling
Sir Dakota Ormsby 69166	July 10, 1909	Dora Sir Gem 39563	Alma Marie 6th Daughter 83257	Fred Michaels
Sir Elmwood Gem 102180		Sir Pieterie Ormsby Mercedes 44931	Dutche Aaltje Salo Augusta 72176	Kroeger Bros.
Sir Pieterie Ormsby Mercedes 12th 81140	Feb. 5, 1911			

TABLE SHOWING CROPPING SYSTEM OF THE MEMBERS OF THE CIRCUIT

	F.C.Micheals	John Tellman	John Klusman	Robt. Rusch	Wm. Neas	Geo. Holle	Kroeger Bros.	Chas. Klusmann	D.Schwarting	Frank Gaebe	John Christensen & Son	Henry Holle	Wm.. Tellman	Average
Number of cattle in herd.....	19	30	35	35	35	12	30	30	85	28	60	30	32	31.23
Acreage in farm.....	320	920	480	600	640	640	640	380	480	640	1000	636	800	628.92
Acreage in native pasture.....	160	800	320	300	160	360	240	200	260	490	800	300	800	328.46
Acreage in tame pasture.....							50			150	15	18		6.88
Acreage prairie hay cut in 1911.....	50	60	25	50	80	4	80	80			100	20	50	57.61
Acreage tame hay cut in 1911.....		80	15	20	2	26	24	8	25	20	1		1	18.46
Acreage corn grown in 1911.....	15	7	25	15	20			15	15	20	28	28	18	16.88
Acreage millet grown in 1911.....	12	20	25	20	16	12	12	15	25	20	10	16	20	17.15
Acreage wheat grown in 1911.....	60	120	72	90	75	60	108	70	96	70	105	35	112	85.63
Acreage oats grown in 1911.....	25	50	25	30	25	40	32	25	30	30	45	25	34	32.00
Acreage of other grain grown 1911.....	10	20	10	10	7	6	50	15	15	9	40	6	14	16.23

19
535

North Dakota Agricultural Experiment Station

Dry Farming Investigations in Western North Dakota

By John C. Thysell, Dickinson, N. D.
H. C. McKinstry, Hettinger, N. D.
R. S. Towle, Edgeley, N. D.
Arthur J. Ogaard, Williston, N. D.

Assistants in Dry Land Agriculture U. S. Department
of Agriculture

Bulletin No. 110

Agricultural College, North Dakota

FEBRUARY, 1915

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The bulletins of this Station are sent free to residents of the State. Names will be entered in the regular mailing list upon request.

*Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

TABLE OF CONTENTS

INTRODUCTION	159
PRECIPITATION	161
EVAPORATION	167
LENGTH OF FROST FREE PERIOD.....	169
SOIL MOISTURE	172
Moisture Storage	172
Moisture Reduction	174
CROPS AND VARIETIES	176
Varieties Used	176
Rates of Seeding	176
Grain Crops (Average Yields.)	178
Forage Crops (Average Yields.).....	179
ROTATION OF CROPS	180
Summer Tillage in Alternate Cropping.....	181
Summer Tillage in Rotation.....	182
Green Manure	186
Manured Fallow	188
Corn	189
Sodding	191
Crop Sequence	193
TILLAGE	200
Fall vs. Spring Plowing	200
Disking vs. Plowing Corn Stubble.....	200
Harrowing	201
Weeding	201
Cultivating	201
GENERAL DISCUSSION	201
CONCLUSIONS	203
PRECIPITATION TABLES	204



Grounds at Edgeley.



Grounds at Williston.

INTRODUCTION

The successful farming of the areas of low rainfall in North Dakota is vital to the future development of the state. Approximately three-fifths of the state lies west of the hundredth meridian and has a normal annual rainfall of sixteen inches or less. In this area there is much fertile soil that is potentially fitted for agricultural purposes which should sustain a large population. During the period of settlement of this region, methods of farming were followed which were unsuccessful and unprofitable, with the result that many sections are regarded as more or less hazardous for cropping.

It is the plan of the Experiment Station through investigations at the Sub-Stations, its Soil Survey, and the Demonstration Farms, to gather information which will enable it to map the State of North Dakota into regions and to state what crops, crop sequence, tillage methods and methods of farm management are adapted to each region. The purpose of the investigations reported in this bulletin has been to determine the best methods of soil cultivation and crop rotation for the conservation of moisture and maintenance of humus in the soils of the Great Plains area.

The investigations presented give part of the results of the work that has been performed in North Dakota. In 1906 the Office of Dry Land Agriculture, U. S. Department of Agriculture, began a series of cooperative trials throughout the Great Plains area. Due to the fact that North Dakota possessed four well equipped sub-stations favorably located for this work, arrangements were made to carry on cooperative work with them. J. H. Shepperd, Agriculturist of the North Dakota Experiment Station, in conference with E. C. Chilcott of the U. S. Department of Agriculture, planned the trials and experiments which should be carried out and directed them. These trials were based largely upon methods of cropping and tillage suggested as important to the region. The Agents of the U. S. Department of Agriculture and the Superintendents of the Sub-Stations have carried out the work and recorded the data.

THOMAS COOPER, Director.

DRY FARMING INVESTIGATIONS IN NORTH DAKOTA

North Dakota is essentially a dry farming State. Practically five-sixths of its total area receives an average annual rainfall of less than twenty inches. (See Figure 1.) While this portion of the State is better adapted to grain raising than most of the Great Plains, conditions are sufficiently adverse to require the best dry farming methods for successful returns.

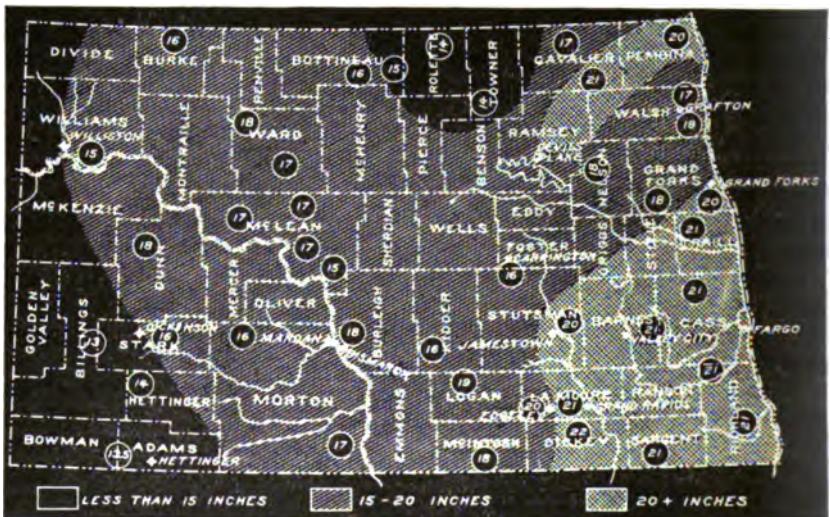


Fig. 1.—Map of North Dakota showing graphically the average annual rainfall distribution. The figures within the circles represent approximately the average annual rainfall in inches at points where ten or more years' records have been available.

The Office of Dry Land Agriculture, United States Department of Agriculture, cooperating with the State Experiment Station, is conducting a series of rotation and tillage experiments at four substations in the State, namely, Edgeley, Dickinson, Williston and Hettinger. The purpose of these experiments is to get a better understanding of the fundamental principles involved in the production of crops under semi-arid conditions. The results thus far obtained have confirmed some ideas concerning dry-land crop production, while others have apparently been upset.

The data presented in this bulletin include weather records, a brief mention of the relation of soil moisture storage and reduction to crop production, and some of the results thus far obtained from the rotation and tillage experiments. The number of

seasons furnishing data varies with the station. At Edgeley the work was begun (1) in 1906, at Dickinson in 1907, at Williston in 1909, and at Hettinger in 1910. Because of the uniform treatment of the land preceding the first year's crop, the first year's yields have not been used in this bulletin.

The land on which these experiments are conducted at each station is as uniform as could be secured. The same general type of soil prevails at three of the stations: Williston, Dickinson and Hettinger, while at Edgeley the texture is heavier with a subsoil of undecomposed shale (2) which in places is not more than eighteen inches below the surface. The experiment fields are divided into one-tenth acre plats which are so arranged as to compare the different rotation and tillage methods.

The management of the plats is essentially the same at all stations, but due attention is given local problems and practices of the locality surrounding the station. The method of work adopted was that of raising the standard crops of each section both in rotations and by different methods of preparation under systems of continuous cropping. In no case have rotations requiring more than six years been used. Those of even this length have been tried only when tame grass crops have been included. More of the work has been done with three and four-year rotations.

The more important climatic conditions are recorded daily and their effect upon crop growth is noted. The amount of soil moisture available at different times during the season is carefully determined and recorded.

PRECIPITATION

The amount of rain that must fall during a given season to insure a good crop is dependent chiefly upon its character and distribution. E. C. Chilcott, (3) referring to rainfall conditions in the Great Plains, says, "It is not an unusual occurrence to have a single downpour of rain which exceeds in amount the normal precipitation for the month in which it occurs. These torrential rains frequently come with such force as to puddle the soil surface, thus making it impervious to water and resulting in the utilization of but a small percentage of the precipitation. On the other hand, showers of less than half an inch do very little good, as the water generally evaporates from the surface without penetrating sufficiently to be of any use to the growing plants or to add to the water being stored in the soil." What has here been said concerning the

1. New rotations were added at Edgeley in 1907 and 1908. Some were also duplicated in 1908.

2. This condition is typical of a narrow strip of territory extending from Edgeley to the South Dakota line.

3. Some Misconceptions Concerning Dry Farming, U. S. Department of Agriculture Yearbook, pp. 247-256, 1911.

irregularities of rainfall in the Great Plains will apply to the plain region of North Dakota.

The rainfall data are presented in such form as to show the monthly, seasonal and annual distribution. The periods covered at each station by these data are considerably longer than the periods of experimentation. For instance, the Williston records extend far back as 1879, while the experiments under discussion have been conducted only since 1908. The Dickinson records go back to 1892. Up to 1906 they were kept in the city. Since that time they have been kept at the sub-station. The Edgeley records extend back to 1901 only. In order to obtain average rainfall for the Edgeley locality that would cover a period long enough to establish a fairly fixed normal, an average covering the years 1900 was constructed from the records of three nearby Weather Bureau stations: Jamestown, Ashley and Berlin. The Hettinger data has been taken mostly from the records of New England Weather Bureau station thirty miles northwest. Since 1901 records were kept at Hettinger. All rainfall data up to the beginning of the experiments at each station have been taken from the Weather Bureau Records (1).

In Figure 2 is presented a chart showing the monthly distribution of rainfall at Williston, Dickinson, Edgeley and Hettinger. It will be observed that the greatest amount of rainfall occurs during the summer months and the least during the winter. The highest average for any one month is shown for June. This is uniformly true for the entire State. At three of the stations, Williston, Dickinson and Hettinger, May ranks next to June in amount. While at Edgeley July comes next to June in this respect. In the western half of the State, May usually has a higher average than July. In the eastern half the reverse is usually the case. Hence Edgeley's May average is not out of accord with that of other points in that part of the State. The rainfall is usually been slightly heavier during the fall months than during the spring months.

Figures 3, 4, 5 and 6 show the annual and seasonal distribution of rainfall at each station. The upright columns represent the seasonal and total precipitation for each year, and the heavier lines running horizontally through these columns represent the average annual and average seasonal rainfalls. It will be observed from a study of these charts that the rainfall for 1910 and 1911 was normally low for all stations. This explains the very low average yields obtained during those years. (See Table IV.)

1. Previous to the taking up of the observations at Williston in 1893 by the Weather Bureau, the records had been kept at Fort Buford by the Signal Service Corps.

2. Includes rainfall from April 1st to July 31st.

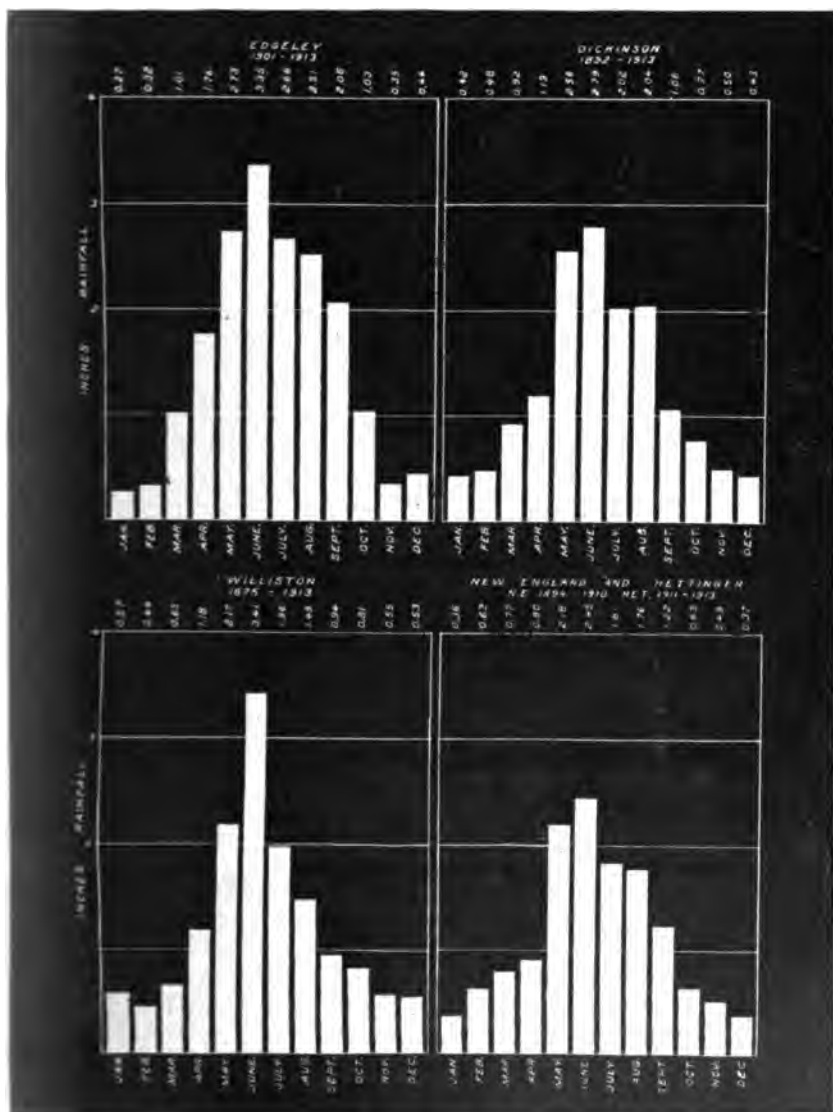


Figure 2. Chart showing monthly distribution of rainfall at each sub-station.

Studying the precipitation of the years during which the experiments were conducted at the different stations, it may be said that the rainfall conditions for those periods have averaged approximately normal. That is, there have been about as many seasons when precipitation was above the normal as there have when it was below.

The relation between seasonal precipitation and crop production is brought out rather strikingly in Figure 7. This chart is a graphic comparison of the average annual yields of barley, oats and wheat with the seasonal and annual rainfall. At both Edgeley and Williston it will be observed that the relation is quite close for all crops. An exception at Edgeley in the case of wheat, occurred in 1914. This is explained by the fact that rust affected that crop

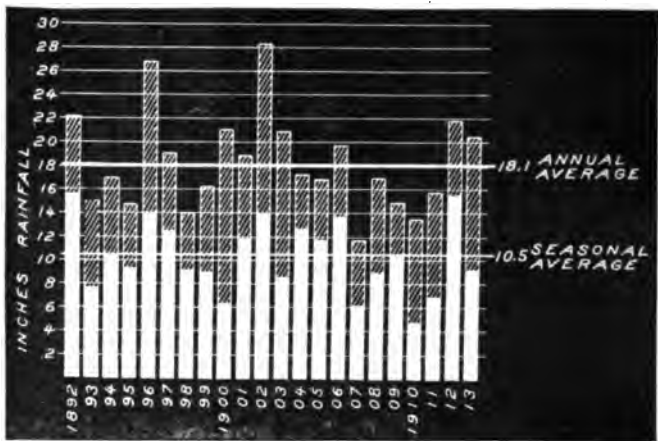


Fig. 3. Average annual and seasonal precipitation at Edgeley, 1892 to 1913.

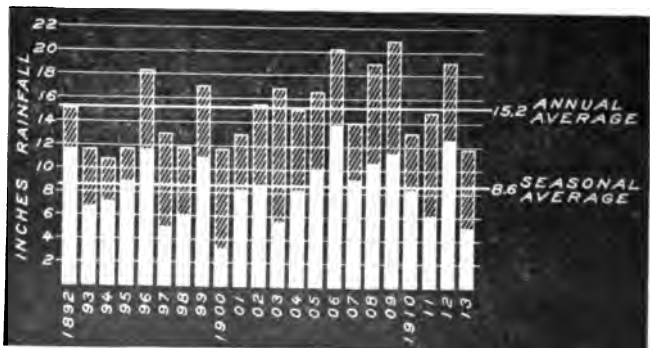


Fig. 4. Average annual and seasonal precipitation at Dickinson, 1892 to 1913.

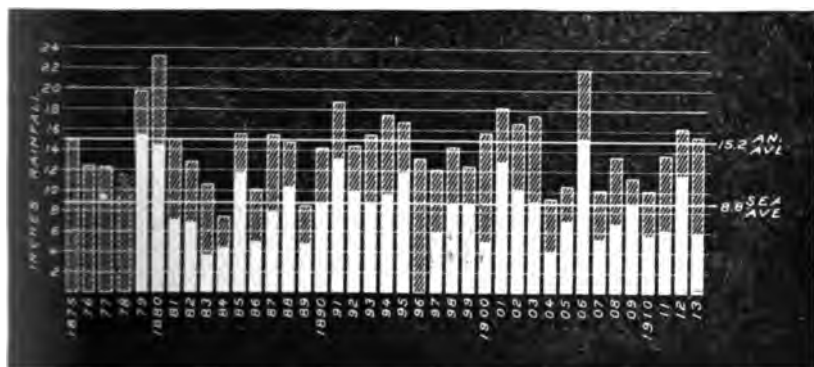


Fig. 5. Average annual and seasonal precipitation at Williston, 1875 to 1913.

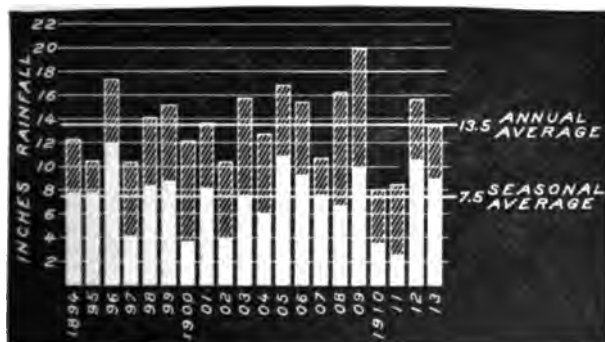


Fig. 6. Average annual and seasonal precipitation at Hettinger, 1894 to 1913.

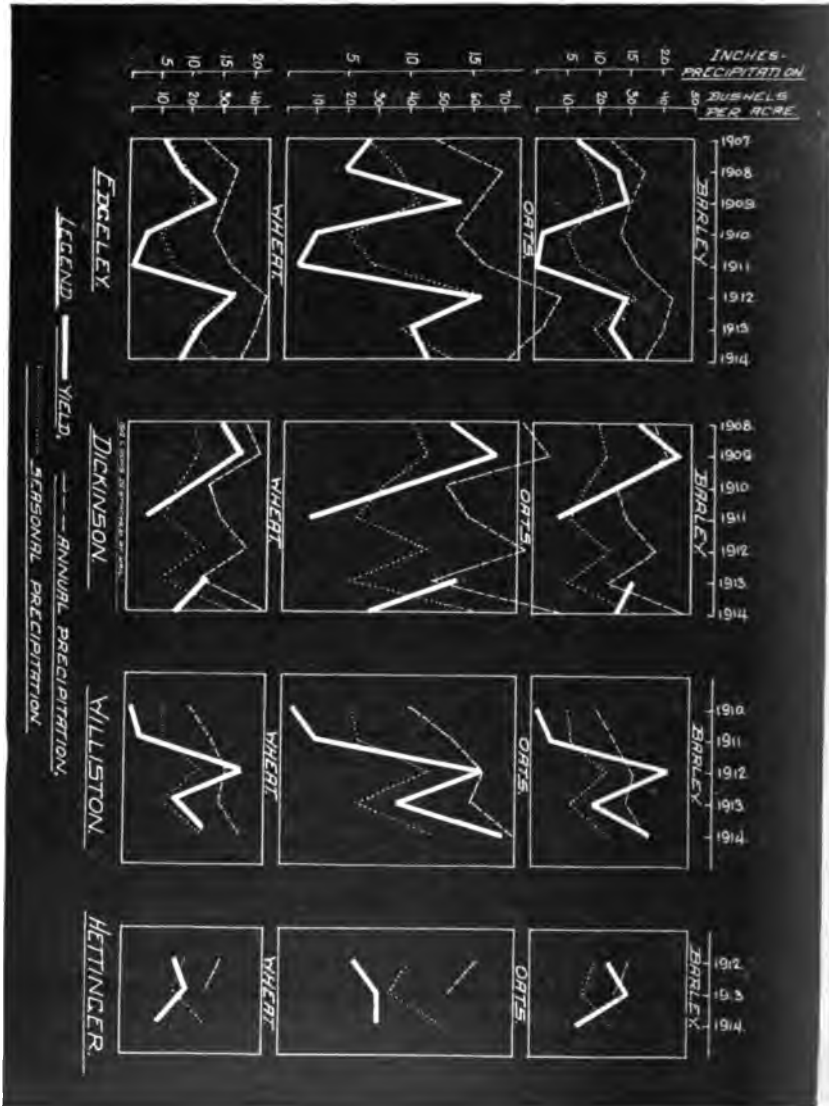


Figure 7. Chart showing the relation of yield to the annual and seasonal precipitation.

very severely that season. At Dickinson there was a close relation between precipitation and crop yields from 1908 to 1911. In 1912 the crops were all destroyed by a hail storm and the land left in a more or less fallow condition. Hence 1913 yields are perhaps higher than would have been the case had the 1912 crop been matured. In 1914 at Dickinson the total seasonal rainfall was the highest for any year recorded. In spite of this fact the crop yields were considerably below normal. This is explained by the occurrence of a period of drought from the latter part of June to the latter part of July. A hail storm before the wheat and oats were harvested also affected the yields of those crops somewhat. At Hettinger, it will be noted, the relation is negative. This is due to unfavorable distribution of the rainfall rather than to its total amount.

It may be observed further that the seasonal precipitation bears a closer relation to crop production than does the annual precipitation.

Taken as a whole, Figure 7 indicates that the experiments here reported have been conducted under conditions where seasonal precipitation is the most important factor influencing the production of small-grain crops.

EVAPORATION

Next to rainfall, evaporation is probably the most important climatic factor affecting crop production. The chief effects produced by it are reduction of soil moisture, acceleration of plant transpiration, and a consequent reduction of efficiency of rainfall. Evaporation is dependent mainly upon three factors, namely, temperature, amount of moisture in the air and wind velocity. Of these, temperature and the moisture condition of the air without doubt have the most influence. A rather striking example of this fact is presented in Figure 8. This chart, constructed from Williston data, shows the relation of temperature, saturation deficit (expression of the relative dryness of the air,) and wind velocity to evaporation. The effect of wind has not been wholly determined, but from a study of the chart it is apparent that evaporation increases and decreases with the rise and fall of the temperature, and inversely with the increase and decrease of the humidity of the air.

The data presented in Table No. I represents evaporation from a freely exposed water surface and should not be considered the same as evaporation from the soil. It does, however, furnish an index to factors which affect evaporation from the soil. As is shown in the table, evaporation varies somewhat with the location of the station. It will be observed that Hettinger shows the greatest seasonal evaporation, Edgeley the least, while Williston and Dickinson are intermediate.

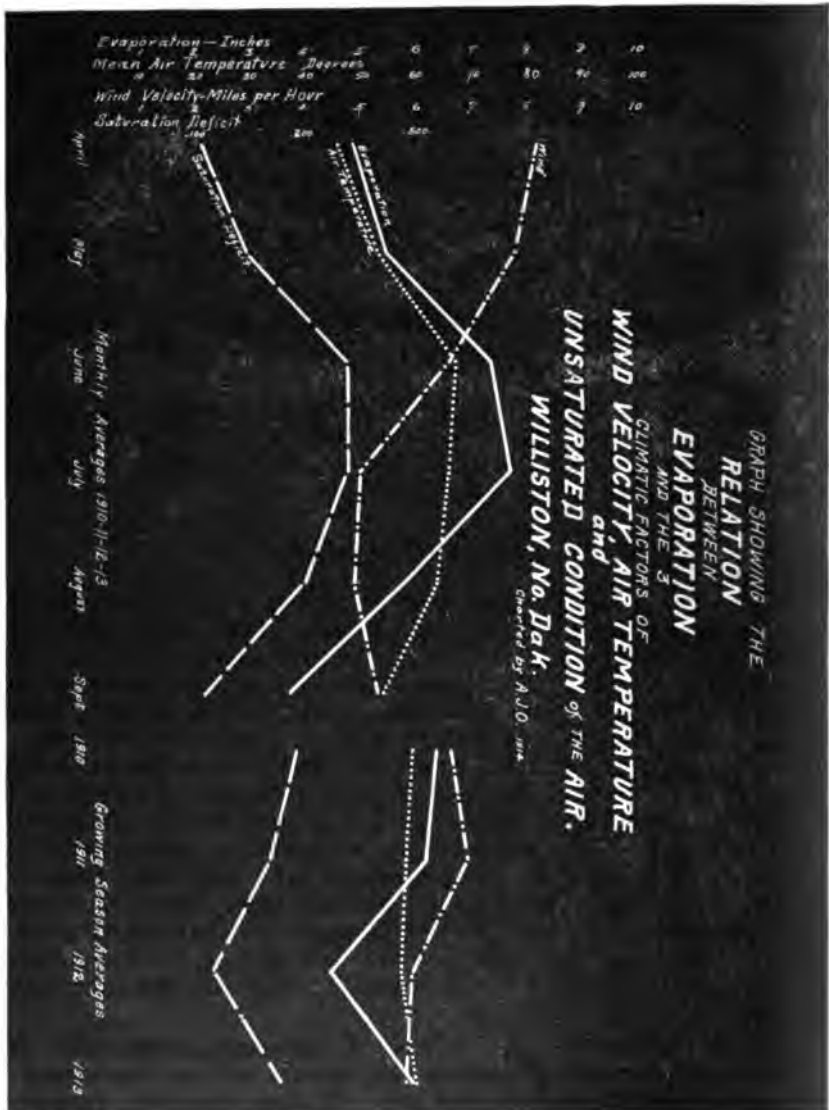


Fig. 8. Chart to show relation between evaporation, wind velocity, temperature and unsaturated condition of air.

TABLE I.—AVERAGED MONTHLY AND TOTAL SEASONAL EVAPORATION FROM A FREELY EXPOSED WATER SURFACE.

Station	No. of Years Records	Average Monthly Evaporation in Inches.						
		April	May	June	July	Aug.	Sept.	Seasonal
Edgeley	7	3.87	4.67	5.66	6.55	5.59	4.08	30.42
Dickinson	7	4.03	4.83	6.21	7.14	6.34	4.19	32.74
Williston	4	4.50	5.78	6.74	7.43	5.92	3.83	34.20
Hettinger	3	4.61	5.23	8.04	8.20	6.61	4.01	36.70

LENGTH OF FROST-FREE PERIOD.

The length of the growing season of any region determines to a large extent what crops and what varieties of a particular crop may be grown. The period between the last killing frost (1) in the spring and the first in the fall is usually identical with the growing season. In the plains region of North Dakota the shortness of the growing season is emphasized by the difficulty often encountered in the successful production of flax, corn, potatoes or garden crops. These crops may be injured by low temperatures at either or both ends of the season. It is, therefore, evident that some knowledge of the frost free period is important.

A chart showing the "Length of Frost Free Periods" at the four substations is given in Figure 9. The horizontal rectangles showing the number of days represent the frost free periods, while the vertical lines show the average dates of the last killing frost in the spring and the first in the fall. The Edgeley frost free season averages 129 days and is the longest. Following is Williston with an average frost free period of 119 days; Dickinson with an average of 110 days, while Hettinger with its very short record has an average of only 100 days. The Hettinger average is low and no doubt additional data will raise it somewhat. Meanwhile data representative of that general area are available from Dickinson records.

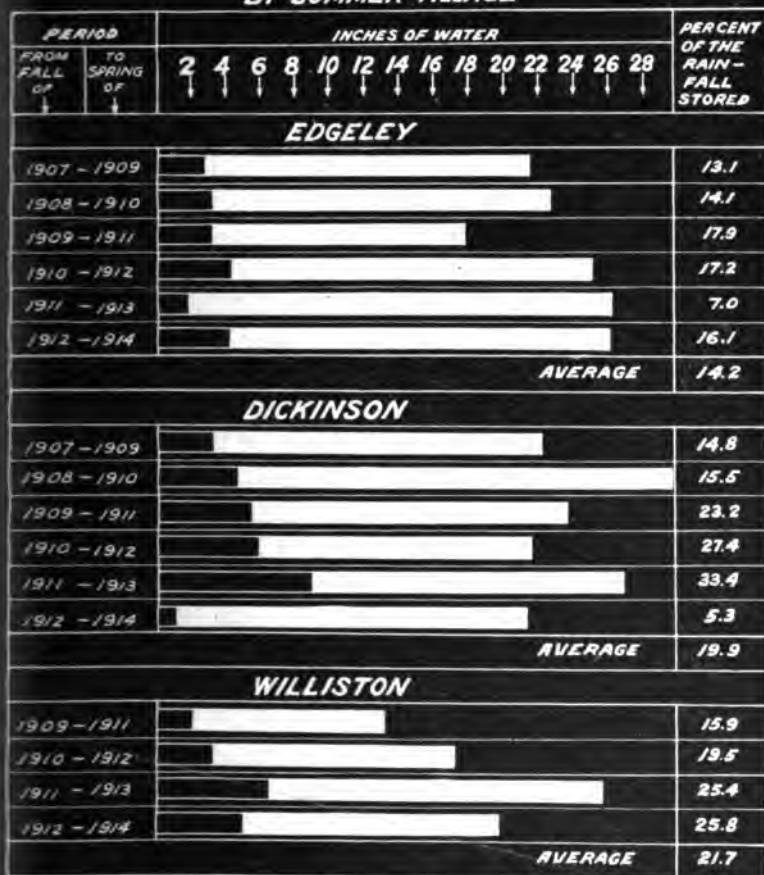
The chart is especially valuable in that it shows about what length of season may be expected for the production of crops that are likely to be affected by frost. The average date of the last killing frost in the spring gives a pretty good measure of the earliest period in the season that such crops should appear above the ground. The average date of the first fall frost may indicate whether early or late varieties of such crops should be grown.

1. A killing frost as referred to in this publication means one that will usually do material injury to such crops as corn, potatoes, or flax.



Figure 9. Chart showing length of frost free period at each sub-station.

CONSERVATION OF SOIL MOISTURE BY SUMMER TILLAGE



LEGEND



Figure 10. Chart showing amount of water and percentage of rainfall stored on summer-tilled land.

SOIL MOISTURE

A deficiency of soil moisture is the distinguishing feature of farming under arid or semi-arid conditions. It is but logical then that along with dry land rotation experiments a study of the soil moisture itself should be undertaken. At all stations, laboratories are equipped for carrying on such studies. Thousands of soil moisture determinations, which throw considerable light on the efficiency of different practices, have been made in connection with tillage experiments.

It is not our purpose to enter into any detailed discussion of soil moisture at this time. However, the extensive work along this line being carried on throughout the Great Plains Area by the Office of Dry Land Agriculture and the Office of Biophysical Investigations has established some general principles, a number of which will here be touched upon. Papers dealing with soil moisture in a more comprehensive way are being prepared.

Differences of opinion with regard to various systems of dry farming are largely due to the imperfect understanding of the principles governing the storage, movement and use of the water in the soils. It is first necessary to know the how, the why and the wherefore and then to be able to adapt this knowledge to changeable farm conditions. Farm practices affecting soil water must be varied to suit conditions. The subject will here be discussed from the standpoint of storage and reduction.

STORAGE OF SOIL MOISTURE—Under average conditions on western North Dakota upland soil, all soil water must be supplied by rains or snow falling upon the surface. There is no underground supply such as a water table, close to the surface as is commonly found in more humid sections. This dry subsoil is an important difference distinguishing our soils from eastern soils and, as we shall see later, it is a characteristic the understanding of which may change many theories that have been held on dry farming methods. When rain falls upon the soil, more or less of the water is lost by runoff, the amount thus lost depending upon the kind of soil, slope of the land, the presence or absence of vegetation, the condition of the upper layer of the soil and the character of the rain. The advocates of deep tillage and plowing to the depth of a foot to sixteen inches argue that the deep stirring and loosening of the soil creates a greater ability to store water. At none of the stations in the Great Plains have these claims been justified by the results of experiments. The writers believe that plowing deeper than necessary to do good work and to create a good seedbed is not an economical or paying practice. However, they do not wish the above to be construed as an argument for mere skinning of the land.

The character of the rain influences the amount of water taken up by the soil. Light showers which do not wet below the upper two or three inches are of very little value for moisture storage as the ground will dry to this depth before the next rain. Growing crops, however, may receive benefit from light showers.

As the upper section of the soil fills with water, the percentage of water increases to a point above which the moisture content will not remain for any length of time. This point has been designated as the normal field carrying capacity of the soil. It is constant for any given type of soil, but differs with different soil textures. It varies from about fifty per cent for a heavy soil (similar to Fargo) to less than ten per cent for open sandy soils. Loam soils of western North Dakota will vary from 10 to 30 per cent with an average of about eighteen to twenty per cent. If the rainfall is sufficiently rapid, the moisture content will go above this point for a time, but the tendency will always be to gradually allow the excess moisture to pass downward into lower depths. When each successive depth has attained its normal carrying capacity, any excess moisture passes through to lower depths.

Under conditions which obtain in western North Dakota, water is seldom stored below the fourth or fifth foot where land is continuously cropped. When the land is fallowed, however, and in seasons of heavy precipitation, moisture has been stored at Dickinson and Williston to the depth of eight or nine feet. At Edgeley the presence of shale at varying depths down to three feet, limits the storage capacity of that particular soil. Figure 10 presents in a graphic way a summary of the efficiency of summer tillage or fallow in conserving in the subsoil the rainfall during the period included between the harvest of one crop and the time of seeding the second year following, a period representing the fallow cycle, or about $1\frac{1}{4}$ years. The percentage of the rainfall stored is not as great as is generally supposed and is not in keeping with the enthusiastic claims made by dry farming faddists regarding the percentage of rainfall that can be stored by moisture conservation methods.

At Edgeley the first three cycles conserved very nearly the same percentage of the rainfall. It will be noticed that the amount stored at Edgeley is very nearly four inches in each fallow cycle. The storage capacity of the soil at this station is so limited by underlying shale that intensive moisture conservation practices are not practical. The Dickinson soil is quite uniform in the upper six feet and is an ideal soil for the conservation of moisture.

The soil at the Williston station is a little more sandy and does not retain as much water. The average soil of the Williston area, however, approximates the Dickinson station soil more closely in this respect.

Variation in distribution of the rainfall is a factor that is not taken into consideration in this chart. Disregarding this disturbing factor, it seems that at Dickinson and Williston about nine inches of rain must fall during the fallow cycle to take care of losses by evaporation during that period. The results indicate that not more than one-third of the total precipitation falling during the fallow period can be stored by summer tillage on western North Dakota soils.

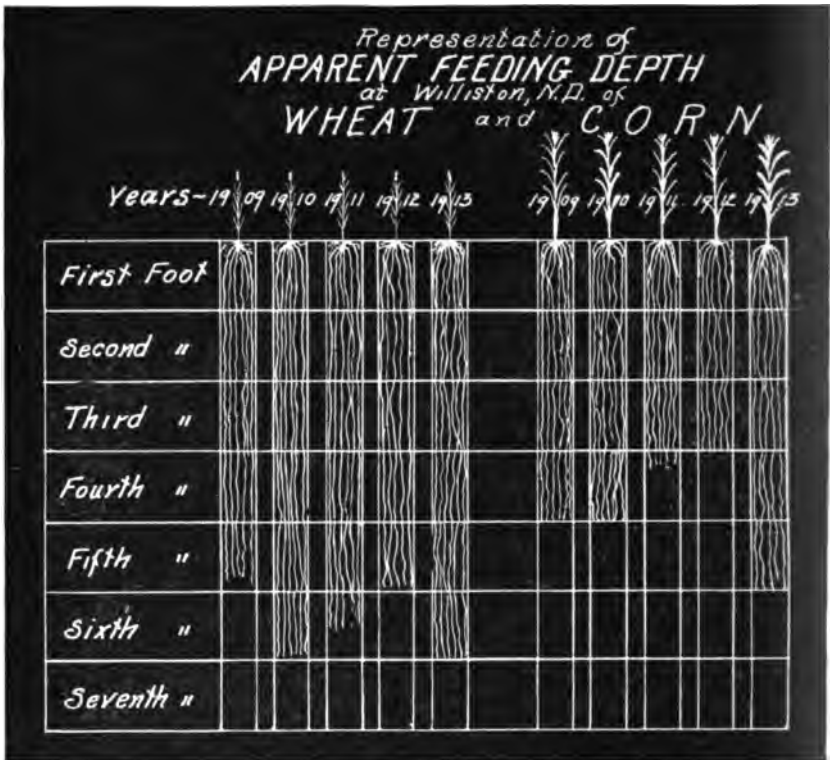


Figure 11. Chart showing the depth to which wheat and corn roots have penetrated at Williston as evidenced by the reduction of the moisture supply.

REDUCTION OF SOIL MOISTURE— Moisture once stored in the soil has three avenues of escape. It may be lost by evaporation from the surface. Plants may take it up and breath it out through their leaves, or the water may seep down to depths beyond the reach of plant roots.

Advocates of dry farming systems based on the "dust blanket" theory strive by maintaining a soil mulch to reduce the loss by evaporation. They reason that by stirring the surface, capillarity will cease to act in bringing up water from the lower depths to the surface. But they fail to take into consideration that because of the absence of a free water table capillarity as a force for moving water upwards ceases and is of no practical importance (1). The apparent benefits, as measured by increased moisture content

1. This statement is not supported by experimental evidence included in this publication; but there is abundant proof of it in data of the Office of Dry Land Agriculture, a part of which has been published by W. W. Burr of that office, in Research Bulletin No. 5 of the University of Nebraska, pp. 75-77.

attributed to the soil mulch, have more than likely been due to the fact that in maintaining the soil mulch, loss of water has been prevented by the eradication of the greatest dissipators of soil moisture, namely, weeds. From the standpoint of moisture conservation, cultivation is beneficial when weeds are destroyed or prevented from growing. This fact should not be taken to mean that less cultivation is necessary but rather that such operations should be performed at times when weeds can be combatted. If the soil checks and cracks deeply, air is allowed to circulate below the normal drying depth of the surface and cultivation is then necessary. Otherwise the soil mulch can be disregarded. Any loss that may take place from seepage to depths below the reach of the plants, would occur only when the storage of water continued until it reached depths below the root feeding zone of crops. In seasons of heavy precipitation, water has been stored below the reach of small grains and corn. Grasses and alfalfa under favorable conditions penetrate to greater depths.

It would not be of advantage to store water at depths beyond which it cannot be recovered by crops. Figure 11 is a diagrammatic representation of the feeding depth of wheat and corn at Williston as shown by moisture determinations made to the depth of ten feet on the alternately cropped and summer tilled plats in the moisture conservation series. It is evident that here wheat feeds deeper than corn. This may be either because the corn plant is not forced to go so deep to obtain sufficient water for its needs or because corn is not able to penetrate as deep as wheat when conditions of drought weaken it. It is also apparent that very little use is made by wheat of water below the sixth foot. It appears that corn does not ordinarily feed to a depth of more than four feet.

If the water passes through the plants of the growing crop it serves the purpose for which it was stored, but when weeds deplete the soil moisture supply it is being wasted without returning any profits to the grower. The importance of weed prevention and destruction is generally underestimated.

Under the growing crops the reduction of soil water goes on until the moisture content is reduced to a point below which, under field conditions, no further reduction takes place. This point has been designated as the minimum point of possible exhaustion and is fairly constant for a given type of soil. The minimum point of possible exhaustion varies from two to three per cent for very sandy soils to over twenty per cent for clay soils.

From the observations made during the progress of these experiments, it is evident that in the Great Plains grains have not been carried from the period of germination to harvest on stored water, unaided by fairly favorable distribution of rainfall during the growing season. An abundance of water in the spring sometimes causes rank growth which cannot be brought to maturity without the aid of subsequent seasonal rainfall. Stored water is a valuable aid in seasons slightly above or below normal in rainfall but occasional seasons of drouth may be expected when stored

water will not sufficiently overcome the deficiency of seasonal rainfall to ward off crop failure.

From the general tone of the discussion of soil moisture, the reader has probably already realized that after investigating the question, the writers do not have enthusiastic faith in so-called "Moisture Conservation" methods. They recognize that there are limitations, not only to the percentage of the total rainfall that can be stored, but also to the value of stored water. They do not believe that the dry farmer of the Great Plains should pin his faith to any special system of tillage as a panacea for dry farming ills.

CROPS AND VARIETIES

The crops grown in the rotation experiments are those which have been most commonly grown in the semi-arid regions. The varieties in most cases have been those considered among the best for the locality, but where later trials have shown others to be better they have been substituted. In Table No. II are given the varieties used at each sub-station at the present time.

TABLE II.—SEED VARIETIES USED IN ROTATION AND TILLAGE EXPERIMENTS AT EDGELEY, HETTINGER, DICKINSON AND WILLISTON

Crop	Edgeley	Hettinger	Dickinson	Williston
Alfalfa	Commercial	Grimm	Grimm	1
Barley	Oderbrucker	White Hulless	Hannchen	Mansury
Brome Grass	Commercial	Commercial	Commercial	Commercial
Corn	N. W. Dent	Golden Dent	N. W. Dent	N. W. Dent
Flax	Wilt Resistant	2	Primost	N. D. No. 155
Oats	Siberian White	Sixty-Day	Early Mount'n	Swedish Select
Peas	Canada Field	Canada Field	White Marrow't	Canada Field
Rye	Spring	Winter	N. D. No. 959	Winter
Sweet Clover	Whiteflow'd	Whiteflow'd	Whiteflow'd	1
Wheat	Arnautka	Kubanka	Kubanka	Arnautka

1. Alfalfa and sweet clover have not been used in rotation experiments at Williston.

2. Wilt resistant.

RATES OF SEEDING—The rate of seeding practiced at these stations has been that which seemed to give the best results for their respective localities.

In all the rotations a uniform rate of seeding for a single crop is used at each station. For instance, if there are twenty-five different experiments in which the same crop is grown, the same rate of seeding is used in each of these twenty-five cases, thereby making the results of all systems comparable in this point. Table No. III shows the rates of seeding used at each sub-station at the present time.

TABLE III.—RATES OF SEEDING FOR THE VARIOUS CROPS USED IN THE ROTATION AND TILLAGE EXPERIMENTS.

Crop	Edgeley	Dickinson	Williston	Hettinger
Alfalfa	8-20 lbs	5 lbs	3	2 lbs
Barley	6 pks	6 pks	8 pks	4 pks
Brome	15-20 lbs	20 lbs	20 lbs	15 lbs
Clover	10-20 lbs	3-15 lbs	15 lbs	15 lbs
Corn	Planted in rows 44 inches apart and thinned to 9 inches in the row			
Flax	2 pks	2 pks	2 pks	20 lbs
Oats	6 pks	6 pks	6 pks	4 pks
Peas	12 pks	10 pks	8 pks	4 pks
Rye	6 pks	5 pks	6 pks	4 pks
Sweet Clover	15 lbs	15 pks	3	15 lbs
Wheat	6 pks	4 pks	4 pks	3 pks

1. Where two rates are given for a crop at the same station, the first rate given is the one used in later years.
2. At Hettinger plants are 18 inches apart in the row.
3. Alfalfa and sweet clover not used in the experiments at Williston.

GRAIN CROPS— Tabular statements of the average annual yields of each grain crop is given in Table No. IV. This is for the purpose of showing the seasonal differences in yields rather than the average production which may be expected in the locality.

TABLE IV.— AVERAGE ANNUAL AND GENERAL AVERAGE YIELDS OF WHEAT, OATS, BARLEY AND CORN FOR EACH SUBSTATION.

Station	No of plts	Bushels Per Acre								
		1907	1908	1909	1910	1911	1912	1913	1914	Av
WHEAT										
Edgeley	28	10.6	16.6	27.6	5.7	1.9	33.9	22.5	16.2	16.9
Dickinson	25		30.0	36.1	21.7	5.9	H	25.9	15.4	22.5
Williston	19				1.8	4.6	37.0	15.3	25.7	16.9
Hettinger	32						16.6	20.3	11.4	16.2
OATS										
Edgeley	30	27.9	19.6	56.0	9.1	4.1	61.9	40.6	46.0	33.2
Dickinson	27		53.3	67.8	35.4	8.9	H	55.6	24.5	40.9
Williston	31				3.5	11.0	63.3	37.8	71.0	37.3
Hettinger	31						23.5	31.7	31.4	28.9
BARLEY										
Edgeley	5	12.9	26.3	29.2	1.9	0.3	29.4	24.2	31.1	19.4
Dickinson	5		33.5	46.4	26.4	8.9	H	31.2	26.5	28.8
Williston	5				1.4	6.1	42.6	19.1	36.7	21.2
Hettinger	5						24.8	30.9	14.9	23.5
CORN										
Edgeley	22			30.4				20.9	14.8	8.3
Dickinson	23			50.0	22.1			27.7	19.0	19.8
Williston	19							25.4	45.1	14.1
Hettinger	26							18.2		6.1

Note:—At Dickinson in 1912 all crops were destroyed by hail.

1. The wheat yield at Edgeley for 1914 were very materially affected by rust and hail.
2. The Dickinson wheat yields for 1914 were damaged about 25 per cent. by hail.
3. The Dickinson oat yields for 1914 were damaged about 50 per cent. by hail.

TABLE V.—A COMPARISON OF THE ANNUAL AND AVERAGE YIELDS OF FORAGE FROM CORN, BROME, ALFALFA AND CLOVER.

Station	No of plts	Pounds Per Acre								
		1907	1908	1909	1910	1911	1912	1913	1914	Av.
CORN										
Edgeley	22	2420	2010	5040	1610	4630	6350	4260	4050	3800
Dickinson	23		2535	5815	3568	4070	H	3590	2980	3760
Williston	19				1791	3962	15767	9064	7686	7657
Hettinger	26						1673	*	8638	5156
BROME										
Edgeley	4	2300	2320	4280	1130	1270	3950	2580	3542	2670
Dickinson	4		2270	3100	2520	750	3310	2670	2850	2500
Williston	4					560	1550	560	570	810
Hettinger	5						1020	750	1040	940
ALFALFA										
Edgeley	2			1000	1000	980	3780	1650	3305	1950
Dickinson	2		1560	3425	1545	710	1550	2320	3180	2040
CLOVER										
Edgeley	1		550	00	850	00	00	500	2480	625
Dickinson	1		4500	460	1250	300	1340	1860	1900	1660

1. Tests on the value of western rye-grass as a substitute for brome grass have been started.

2. Average of two plats.

* No Weights taken.

FORAGE CROPS— In Table No. V are shown the yields of the forage crops grown. Corn is one of the foremost forage crops suited to North Dakota conditions. As a cultivated crop its value in preparing the land for a succeeding small grain crop is shown in another part of this bulletin. In this work it is grown in nearly all the rotations where an intertilled crop is used.

A comparison of yields, especially those secured in 1910 and 1911, shows corn as a feed crop is safer than any of the small grains as grain crops. The yields of corn fodder are also shown to be much greater than those of any of the hay crops discussed in this bulletin and are probably greater than the yields from any hay crop generally grown in North Dakota, with the possible exception of millet.

Brome grass is grown in two rotations. The only difference between these rotations is that in one flax is introduced, thus making that rotation one year longer than the other. In both of them the grass is seeded with wheat on disked corn land and left for two seasons after the wheat crop is removed. At Edgeley and Dickinson very creditable yields have been obtained, while at Williston and Hettinger the yields of hay have been much lighter.

Alfalfa has been grown in but one rotation at each station. It is seeded on fall-plowed land at such time in the early summer as the soil seems to be in the best condition for it. At Edgeley and Hettinger broadcast seeding has been practiced. At Williston, and at Dickinson until 1912, the alfalfa has been drilled solid, while at Dickinson during the last three years it has been seeded in rows far enough apart to cultivate. The best yields have been secured at Dickinson and Edgeley. At Edgeley the average yield has been low in comparison with other forage crops adapted to that region.

Clover is used in a five-year rotation, but has not yet given much success. Failure with it has usually been due to winter-killing. At Edgeley the location of the clover plat is such that in some years it has suffered from soil blowing from adjoining plats. Its production under favorable conditions has been good at times, but on the average it has not proved a profitable crop. At only two stations, Dickinson and Edgeley, have yields been secured. It will be seen from the table that the yields have not varied directly with the seasonal rainfall. The rainfall for 1909 was the highest recorded at Dickinson but nearly as large a yield of clover was produced in 1911 when the rainfall was very low.

ROTATION OF CROPS

Systems of rotation are designed to take the place of the methods ordinarily used, such as cropping to the same crop year after year, or the usual haphazard and indefinite changing of the cropping order. A rotation suitable for any particular region should attain the following ends: a more regular income less dependent upon seasonal conditions; a profitable income in spite of previous long continued cropping, and a more uniform distribution of farm labor throughout the year.

No perfect rotation has yet been devised. To approximate perfection, the nature and importance of the principles involved must be recognized. Fundamentally the so-called "money crops" should be arranged in the rotation where they will be afforded the most favorable moisture and fertility conditions. Summer tilled land and that previously devoted to intertilled crops like corn or potatoes furnish favorable moisture conditions for growing such crops. The fertility is usually kept up by applying manure, plowing under green manure crops, or growing restorative crops like grasses and legumes.

The moisture factor will always be important in western North Dakota. An abundance of fertility will not assure good crops without a sufficient supply of water. Since these soils have not been depleted of their native fertility by cropping, the moisture factor should receive the first consideration.

The relative merits of different systems will be discussed in the light of the data obtained. This may assist the farmer in deciding whether he should summer till, crop every year to the same crop, plow under green manure crops, grow corn, grass crops, or

combine any of these practices as a fundamental part of his cropping system.

In attempting to determine whether a practice pays, at least three factors must be taken into consideration, namely, production, economy of production, and the effects of the practice on soil fertility. Even if a practice or system of cropping produced well, it might be impracticable and unprofitable because of a too-high cost of production, or because of detrimental effects from the standpoint of soil fertility and permanent agriculture.

SUMMER TILLAGE

SUMMER TILLAGE WITH ALTERNATE CROPPING—At each station a series of experiments is conducted in which cropping alternating with summer tillage is compared with cropping continuously to the same crop. Where cropping is alternated with summer tillage the land is cropped one year and summer tilled the next. Two plats are used so that each year there is one plat under crop while the other is summer tilled. In summer tillage the land is plowed either in the fall or late spring and kept clean throughout the season in order to store moisture for the crop the next year. Two plats are devoted to continuous cropping. One is fall plowed while the other is plowed in the spring as shown in the table on fall plowing versus spring plowing, there is but little difference in the yields secured from the two methods. Consequently in the comparison with (cropping alternated with) summer tillage the average yields from both the fall and spring plowed plats is used.

The results presented in Table No. VI show increased yields in favor of summer tillage for the small grains at all stations. The smallest differences are shown at Edgeley, where the results are no doubt affected by shale in the subsoil. On a shallow soil of this type there is usually very little response to methods of moisture conservation.

At Edgeley, summer tillage has given an increased yield over continuous cropping of 1.6 bushels per acre for wheat, 15.7 bushels for oats, and 3.0 bushels for barley. At Dickinson it has given an increase of 12.2 bushels for wheat, 20.3 bushels for oats, and 7.0 bushels for barley; at Williston 5.6 bushels for wheat, 16.5 for oats, and 12.7 for barley, while at Hettinger the difference is 10.3 bushels for wheat, 13.8 bushels for oats and 8.1 for barley.

The average increase in favor of summer tillage for Dickinson, Williston and Hettinger, the three stations where conditions are the most similar, is 7.4 bushels for wheat, 16.6 bushels for oats and 7.7 bushels for barley.

Whether or not the practice of alternating a crop with summer tillage increases the yield sufficiently to make it profitable must be decided by the local conditions influencing the cost of production. It must be considered that twice as much land is necessary for the same acreage in crops and that as land values increase, the comparative value of summer tillage will grow less. The greater part of the work with summer tillage can usually be done when general

farm work is light. The general operating cost would therefore be somewhat reduced.

It is apparent from a consideration of these factors and the yields secured that alternate cropping has not proved to be a profitable practice at any of the North Dakota stations where this work has been conducted, except at Dickinson. At this station its value over continuous cropping is consistently shown.

SUMMER TILLAGE IN ROTATION—There are a number of trials where summer tillage is used in crop rotation. In these trials, the summer tilled land is treated the same as with alternate cropping, but with two or more crops intervening. In Table No. VII are shown the yields received by this treatment compared with the yields of the same crop when grown after small grains in similar rotations.

An increase in favor of summer tillage is shown by the total average in every instance. For Edgeley this difference is 2.9 bushels per acre for both wheat and oats; at Dickinson 9.3 bushels per acre for wheat, and 12.8 bushels for oats; Williston 4.6 bushels per acre for wheat and 6.3 bushels for oats; and at Hettinger 3.4 bushels for wheat and 8 bushels for oats. For all four stations the average difference in favor of summer tillage is 5.0 bushels for wheat and 7.5 bushels for oats.

At none of the stations except Dickinson is there any marked increase in yield in favor of summer tillage, except in dry years when the yields from all methods were generally low. A strong argument in favor of summer tillage is that in a certain measure it insures a fair yield in a season of drouth, but when considered from the standpoint of average production it appears that it is of doubtful value in western North Dakota.

TABLE VI.—COMPARISON OF ANNUAL AND AVERAGE YIELDS SECURED FROM CONTINUOUS CROPPING AND ALTERNATE CROPPING WITH SUMMER TILLAGE

Station	Treatment	No of plots	Bushels Per Acre									
			1907	1908	1909	1910	1911	1912	1913	1914	Av.	
WHEAT												
Edgeley	Con. cropping.	2	5.6	14.3	25.8	4.6	0.6	31.0	14.2	10.3	13.2	
	Summer tillage.	1	9.9	16.0	27.0	5.7	0.7	30.3	16.8	13.0	14.8	
Dickinson	Con. cropping.	2		21.0	26.0	17.8	3.6	H	17.0	8.7	15.6	
	Summer tillage.	1		33.8	35.7	26.8	23.3	H	27.0	20.8	27.8	
Williston	Con. cropping	2				1.5	2.5	29.5	14.3	23.2	14.2	
	Summer tillage.	1				4.2	7.6	39.7	16.5	31.2	19.8	
Hettinger	Con. cropping.	2						13.2	12.3	8.1	112	
	Summer tillage.	1						17.5	37.0	10.0	2.5	
All Stations	Con. cropping	8									13.6	
	Summer tillage.	4									21.0	
OATS												
Edgeley	Con. cropping	2	21.4	16.1	52.2	8.3	0.4	57.1	25.0	33.5	26.8	
	Summer tillage.	1	36.7		55.6	15.3	8.9	80.9	49.3	50.6	42.5	
Dickinson	Con. cropping.	2		40.6	57.2	29.0	4.1	H	38.7	14.9	30.8	
	Summer tillage.	1		61.9	66.6	50.6	26.1	H	60.0	41.4	51.1	
Williston	Con. cropping.	2				2.7	8.6	47.4	32.5	56.1	29.5	
	Summer tillage.	1				7.7	15.6	82.2	41.3	83.4	46.0	
Hettinger	Con. cropping.	?						34.6	32.9	36.9	34.8	
	Summer tillage.	1						48.4	58.4	39.1	48.6	

GREEN MANURE

There is a difference of opinion as to the effect on soil fertility of allowing the land to lie bare. The practice is generally thought to be destructive of humus. Due to the high straw yields on fallow plats, approximately as much straw is taken off one acre of fallow as is produced on two acres continuously cropped. Both of these systems are deficient in that no provision is made for directly or indirectly maintaining soil fertility. A modified form of summer tillage is the plowing under of a crop. This practice of green manuring, aside from being a partial fallow, supplies the material necessary for restoring or keeping up the humus content of the soil. In this way both soil fertility and moisture conservation should be attained.

In the work here reported three crops have been used as green manures, namely, rye, peas, and sweet clover. Williston does not use sweet clover. Winter rye is used at Williston and Dickinson and spring rye at Edgeley and Hettinger. A supposed advantage of winter rye is the fact that this crop can be plowed under earlier in the season. This gives an additional month for moisture conservation which is of considerable advantage in the western portion of the State.

Sweet clover being a biennial plant is seeded with the grain crop of the previous year. Thus no extra cultivation is required for its production. In the eastern parts of the State this method of handling the land is probably more nearly like the ordinary method of handling fallow than any of the other methods of summer tillage or green manure except that, with the ordinary fallow, weeds are allowed to take the place of the green manure crops.

These crops are grown in a series of four-year rotations planned according to the following general schedule: small grain, corn, small grain, green manure, and then repeated. Another set of rotations substitutes summer tillage for green manure. A comparison of the effect of these methods on the first crop following them is given in Table No. VIII.

From the standpoint of immediate returns, it is evident that green manuring as compared with clean fallow has not increased the yield of the wheat crop at any of the stations. Where oats followed the green manure we note negative results, except at Williston where oats after the green manures average higher than oats after fallow. This greater advantage in 1913 was due to the weeds choking the oats on fallow. In all probability, with the soil still in almost its original state of fertility, the practice of green manuring will not materially increase the present yields produced under the ordinary fallowing system. While the moisture problem is more important than the fertility problem, as measured by immediate returns, this system will not be generally practiced with profit. Due to the short period of the trials, no reliable data can be given on the matter of residual effects as measured by crops grown several years after the treatment.

SUMMER TILLAGE MANURED

A number of rotations are being conducted at Edgeley to determine the effect of manured summer tillage on the succeeding crops. The manure is applied at the rate of nine loads per acre before plowing the fallow. The arrangement of these rotations with the crops named in the order of their succession on the land is as follows:

Rotation 72	Rotation 18	Rotation 71	Rotation 19
Fallow (Manured)	Fallow (Not Manured)	Fallow (Manured)	Fallow (Not Manured)
Wheat	Wheat	Oats	Oats
Corn	Corn	Corn	Corn
Oats	Oats	Wheat	Wheat

**TABLE IX.—EFFECT OF MANURED FALLOW ON SUCCEEDING CROPS
IN ROTATIONS AT EDGELEY**

Where Wheat Follows Fallow							
Rotation	1909	1910	1911	1912	1913	1914	Av.
Fallow, Rotation 72, Manured,							
" " 18, Unmanured,							
Wheat, Rotation 72,	29.0	9.3	4.4	36.9	32.5	17.5	21.6
" " 18,	22.6	7.8	3.7	34.2	23.3	16.8	18.0
Difference in favor of manure,	6.4	1.5	0.7	2.7	9.2	1.2	3.6
Corn, Rotation 72,	5280	1930	5450	6380	4460	4430	4660
" " 18,	4680	1300	4250	5500	4180	3500	3901
Difference in favor of manure,	600	630	1200	880	280	930	760
Oats, Rotation 72,	54.2	6.9	8.1	59.9	63.2	55.0	41.2
" " 18,	55.3	6.8	1.2	62.8	39.3	46.8	35.3
Difference in favor of manure,	-1.1	0.1	6.9	-2.9	23.9	8.7	5.9
Where Oats Follows Fallow.							
Fallow, Rotation 71, Manured,							
" " 19, Unmanured,							
Oats, Rotation 71,	62.0	8.7	12.3	63.4	66.6	47.4	43.4
" " 19,	59.3	12.5	6.7	74.4	41.8	45.3	40.0
Difference in favor of manure,	2.7	-3.8	5.6	-11.0	24.8	2.1	3.4
Corn, Rotation 71,	5100	2330	4850	6875	4630	4240	4670
" " 19,	5130	1500	3700	5800	3990	2570	3950
Difference in favor of manure,	-30	830	1150	1075	640	670	720
Wheat, Rotation 71,	26.8	5.1	3.7	32.0	27.2	17.2	18.7
" " 19,	25.1	5.6	4.1	36.3	21.8	17.2	18.4
Difference in favor of manure,	1.7	-0.5	-0.4	-4.3	5.4	0.0	0.3

Similar trials on a more extensive scale are being conducted at Hettinger but are not yet sufficiently advanced to give any comparative results. The yields for Edgeley from 1909 to 1914 are given in Table No. IX.

Wheat following immediately after manured fallow has given an average yield of 3.6 bushels more than where the fallow was not manured. Oats show an average increase of 3.4 bushels per acre for the manured fallow, although in two years out of the six the unmanured land gave the highest yields.

Corn has been grown the second year after fallow in all of this work. Where the fallow was manured the yields have been consistently better than where it was not manured, the average difference running between 700 and 800 pounds total weight per acre.

On land fallowed three years previously, wheat showed practically no effect from the manure applied to the fallow. Oats in similar position showed in three years out of five better yields on the land that had been manured. In the other two years there was but little difference in the yields from the two methods.

In four-year rotations, nine loads of manure, applied once every four years on fallow, has evidently produced the following increase in yield: In one case where wheat followed fallow, 3.6 bushels of wheat, 760 pounds in total weight of corn, and 5.9 bushels of oats; while with oats following fallow the increase was 3.4 bushels of oats, 720 pounds of corn and .3 of a bushel of wheat.

CORN

Intertilled crops are grown in rotations where the farmer wishes to produce a feed crop instead of allowing his land to lie idle as in the case of fallow. Corn uses a relatively large amount of moisture for growth; but due to shading and cultivation it is probable that corn land allows less run-off and evaporation than a bare cultivated fallow. Fallow land, however, at seeding time usually contains more moisture for the next crop than corn land. The comparison of the yields secured on land previously fallowed with land previously cropped to corn is given in Table No. X.

For the production of wheat, fallowing has produced average yields from twenty to thirty per cent higher than those secured on corn land at all stations except Edgeley, where no advantage is indicated. From a close study of the table, it is apparent that at Edgeley no year shows any considerable advantage for one practice over the other. At Dickinson, the differences are small except for the year 1911, when fallowing yielded 22.1 bushels as compared with 4.7 bushels produced on corn land. The straw growths for that year were about equal but the wheat on fallow was later in flowering and escaped the blighting effect of a short period of hot winds which caught the wheat on corn land while flowering. Fertilization of the wheat was thus almost entirely prevented on corn land. Williston data reveal nothing but small differences until 1914. The fallowed plats in that case, by virtue of being less advanced during the midsummer drouth, were able to recover better than the corn plats. At Hettinger, the year 1913 shows eleven bushels advantage in yield for fallow. Lack of moisture during the period of filling was the chief handicap of the wheat grown on corn land. The wheat yields for all stations show a 3.3 bushel average difference in favor of fallowing.

TABLE X.—SHOWING YIELDS OBTAINED ON CORN LAND AS COMPARED WITH FALLOWED LAND.

Station	Treatment	Bushels Per Acre								
		1907	1908	1909	1910	1911	1912	1913	1914	Av.
WHEAT										
Edgeley ...	After Corn	13.2	18.2	28.1	5.6	2.3	34.0	23.4	17.0	17.7
"	" Fallow	10.9	15.8	27.5	8.0	3.2	35.4	26.1	16.0	17.9
Dickinson ..	" Corn		32.9	38.3	23.2	4.7	H	27.8	14.9	23.6
"	" Fallow		33.6	36.9	26.0	22.1	H	27.2	19.2	27.5
Williston...	" Corn				0.9	5.3	39.2	15.3	20.8	16.3
"	" Fallow				4.9	8.2	39.9	17.8	30.3	20.2
Hettinger ..	" Corn						16.9	18.9	11.6	15.8
"	" Fallow						19.9	29.6	11.8	20.4
All Stations	" Corn									18.4
" "	" Fallow									21.5
OATS										
Edgeley ...	After Corn	23.0	20.3	56.3	7.9	4.4	63.4	42.9	44.9	32.9
"	" Fallow	33.8	19.9	59.0	11.0	9.3	70.9	54.1	48.1	38.3
Dickinson ..	" Corn		62.4	74.2	39.6	10.9	H	59.5	24.5	45.2
"	" Fallow		57.7	70.1	47.2	29.8	H	57.1	37.4	49.9
Williston...	" Corn				2.2	13.3	65.9	43.9	65.2	38.1
"	" Fallow				5.9	16.8	77.1	39.8	79.7	43.9
Hettinger ..	" Corn						25.8	41.4	37.0	34.7
"	" Fallow						27.3	38.3	30.8	32.1
All Stations	" Corn									37.7
" "	" Fallow									41.0
BARLEY										
Edgeley ...	After Corn	18.3	31.9	33.1	2.9	0.4	30.2	37.1	33.1	23.4
"	" Fallow	16.0	24.2	28.3	2.2	0.8	32.3	26.8	29.4	20.0
Dickinson ..	" Corn		45.6	53.8	28.6	12.3	H	44.8	39.1	37.4
"	" Fallow		30.0	50.0	24.0	19.1	H	36.9	35.2	32.5
Williston...	" Corn				0.4	4.2	50.8	28.6	53.5	27.5
"	" Fallow				5.2	12.7	54.4	21.9	49.7	28.8
Hettinger ..	" Corn						13.5	21.0	10.2	14.9
"	" Fallow						37.8	38.8	18.7	31.8
All Stations	" Corn									25.8
" "	" Fallow									28.3

The effect of fallow on the oats crop following has been less than on wheat. The differences in favor of fallow are from 11 to 16 per cent at three stations, while at Hettinger the average yields are in favor of corn land. The oat yields for all stations show a 3.3 bushel average difference in favor of fallowing.

The results for barley are taken from data recorded for only two plats and for this reason are not to be considered final or conclusive. Edgeley and Dickinson show advantages for corn land. Williston yields are slightly favorable to fallow, while Hettinger results are decidedly so.

The arguments which can be advanced for fallowing rather than growing corn in western North Dakota are; slightly increased average yields, less expenditure of labor, and a greater insurance of a crop in some seasons of drouth.

The practice of growing corn rather than fallowing can be defended by referring to the following established facts: Corn is one of the foremost forage crops suited to North Dakota conditions. The value of the corn (grain and fodder) produced, when fed to livestock, overweighs the greater insurance of fallow to produce a crop during some seasons of drouth and the slight increase of yields brought about by fallowing. By reference to Table No. IV, the reader will be given an idea of the possibilities of corn production with our present varieties. The average yield of fodder at the four stations has been about two and one-half tons. With livestock sufficient to consume the silage or fodder produced on the corn land in the rotation, the fallow system should not be commonly practiced in North Dakota. When the value of the manure applied to the land is considered, the placing of corn in the rotation plan should only be delayed until sufficient livestock could be secured. Lack of capital to buy livestock and to tide over seasons of crop failure are conditions very common in a comparatively new section of the country. In view of these conditions, fallowing can be made temporarily a part of the cropping system. It should be confined to proportions in keeping with the actual benefits which it may furnish in the way of insurance against total failure and should not interfere with the production of as much corn as can be consumed by livestock on the farm.

SODDING

Instead of combining the two problems of moisture conservation and the maintenance of soil fertility in one year's treatment, the restorative crop is sometimes grown with rather a decided reduction of moisture. This is the case when crops like alfalfa, brome grass, timothy, rye grass, or clovers are grown for hay and pasturing purposes. The sodding effect is beneficial in adding organic matter to the soil, but the moisture content on sod land is usually reduced to a minimum. The immediate returns as measured by the following crop are generally low, unless seasonal precipitation is high. The soil after having grown a grass crop is practically dry to the full extent of the feeding depth.

Yields of oats following sod crops are presented in Table No. XI.

The results for Edgeley show an advantage of approximately 11.0 bushels per acre in favor of oats following small grains as compared with oats following alfalfa. Compared with brome grass

[illegible]

or clover an advantage of 2.7 bushels is shown in favor of small grains as a previous crop.

At Dickinson the yield of oats after brome grass is approximately six bushels greater than that after small grains. After alfalfa there is a difference of four bushels and after clover a difference of 1.4 bushels in favor of small grains. The average yield after all grasses at Dickinson is 3.7 bushels more than after small grains.

At Williston the yield of oats following brome grass shows a decrease of approximately 2.0 bushels when compared with oats following small grains, while with oats following clover there is an increase or advantage of 5.0 bushels. Oats following a sod crop have given an average yield of 1.4 bushels more than when following small grains.

Due to the difficulty in getting stands, the results in some cases are not directly attributable to the effects of the grass crop seeded. Alfalfa and brome grass are sometimes difficult to kill out. If the breaking of the sod is done when the roots are growing and tender, and a dry period follows, very little trouble need be anticipated. However, if the roots are dry and in rather dormant condition and rainy weather sets in after breaking, a grassy field will result.

No residual effects have been noticed on wheat yields on land sodded three years previous at either Edgeley or Dickinson. An apparent increase of nearly two bushels has been obtained at Williston. An appreciable effect could scarcely be expected until cropping had reduced the native fertility to a lower degree. At present the growing of grasses cannot be undertaken with any degree of expectation of immediate increase in yields of the crops following them. However, in livestock farming a certain amount of pasture and hay is necessary. Under proper management the grass project can be made a profitable one.

CROP SEQUENCE

One of the significant observations made in connection with a crop rotation is the effect of one crop on those which follow. So far as these experiments are concerned at present, that effect is mostly soil moisture reduction. The extent to which this effect operates depends on the order of the crops in the rotation.

The wheat yields for all stations are uniformly consistent as related to the previous crop. The highest yields at all stations are produced after corn; the second highest after oats, and the third on land continuously cropped to wheat.

The effect of crop sequence upon oats is not so uniformly consistent. Except at Edgeley, the yield following corn ranks first. Here there is an increase of 0.8 bushels over corn land in favor of land previously cropped to wheat. At Hettinger the yields of oats after corn and after oats have been equal. The average for all stations shows the highest yields on land previously cropped to corn; the second highest on land previously cropped to barley or wheat, and the lowest yields on land continuously cropped to oats.

**TABLE XII.—CROP SEQUENCE. WHEAT YIELDS FOLLOWING CORN,
OATS AND WHEAT.**

[illegible]

TABLE XIII.—CROP SEQUENCE. OAT YIELDS FOLLOWING CORN, BARLEY, WHEAT AND OATS.

[illegible]

		Pre- vious Crop	No of plts	Yield in Bushels									
				1907	1908	1909	1910	1911	1912	1913	1914	Ave	
EDGELEY													
In rotations	Corn	1	18.8	31.9	33.1	2.9	0.4	30.2	37.1	33.1	23.1		
" "	Oats	1	10.6	26.0	32.7	1.4	0.1	34.0	18.9	33.6	19.1		
Continuous Cropping	Barley	2	9.8	24.6	25.9	1.4	0.0	25.4	19.2	29.6	17.1		
DICKINSON													
In rotations	Corn	1		45.6	53.8	28.6	12.3	H	44.8	39.1	38.1		
" "	Oats	1		34.4	49.2	19.8	2.4	H	20.2	13.3	23.1		
Continuous Cropping	Barley	2		23.8	39.4	29.7	5.4	H	27.0	22.6	25.1		
WILLISTON													
In rotations	Corn	1				0.4	4.2	50.8	28.6	53.5	27.1		
" "	Oats	1				0.2	4.6	20.0	15.6	36.7	17.1		
Continuous Cropping	Barley	2				0.7	4.6	38.9	14.6	21.7	16.1		
HETTINGER													
In rotations	Corn	1						13.5	21.0	10.2	14.1		
" "	Oats	1						22.9	28.0	10.0	23.0		
Continuous Cropping	Barley	2						24.9	33.4	12.8	23.1		
Average of all Stations													
In rotations	Corn	4									25.8		
" "	Oats	4									21.1		
Continuous Cropping	Barley	8									20.6		

TABLE XV.—FALL PLOWING VERSUS SPRING PLOWING.

[illegible]

TABLE XV. (CONTINUED) FALL PLOWING VERSUS SPRING PLOWING

Station	Treatment	No of plts	Bushels Per Acre										Av.
			1907	1908	1909	1910	1911	1912	1913	1914			
B A R L E Y													
Edgeley . .	F.P.	1	9.4	24.2	24.7	1.6	0.1	26.5	10.2	26.9	16.7		
	S.P.	2	10.4	25.5	29.9	1.3	0.0	29.1	18.4	33.0	18.5		
Dickinson	F.P.	1		24.0	39.0	31.1	1.2	H	34.8	20.2	21.5		
	S.P.	2		34.0	44.5	24.1	6.0	H	19.7	19.2	24.6		
Williston .	F.P.	1				0.6	3.3	46.1	14.8	22.0	17.4		
	S.P.	2				0.5	5.2	30.9	15.0	29.1	16.1		
Hettinger	F.P.	1						23.5	27.1	9.2	19.9		
	S.P.	2						24.6	33.8	18.2	25.5		
Average . .	F.P.	4									18.9		
	S.P.	8									21.2		
CORN FODDER (POUNDS PER ACRE)													
Edgeley . .	F.P.	6	3130	2180	4865	1390	4730	5075	3790	3780	3745		
	S.P.	21	2190	1990	5110	1660	4560	6430	4470	4170	3825		
Dickinson	F.P.	5		2130	5760	3640	3480	H	4130	2640	3630		
	S.P.	17		2740	5590	3650	4200	H	3510	3170	3810		
Williston	F.P.	5				1704	3331	6908	9340	7500	7655		
	S.P.	13				1612	4151	5817	8780	7672	7545		
Average . .	F.P.	16									5010		
All Stations	S.P.	51									5060		

In the barley tables a general relation is shown in the yields as effected by the previous crop. There is an exception at Dickinson, where continuously cropped land yields an increase of 2.3 bushels over barley following oats, while at Hettinger the yields are not comparable because of a difference of soil type. In the final average, however, corn land ranks first, oats land second, with land continuously cropped to barley producing the lowest yields.

FALL PLOWING VERSUS SPRING PLOWING

In considering the results of this trial of fall plowing compared with spring plowing it should be remembered that in practice it would not be possible to spring plow a very considerable acreage without having some of it done at much more unseasonable time than was the case in these experiments. Also that fall plowing could be done in farming practice at times when the results would compare more favorably with the fall plowing represented by this trial.

Time of plowing is a problem that confronts every farmer. The solution is determined largely by the local conditions. Rules that would apply under one condition might not apply under another. It is evident from a study of Table No. XV that spring plowing has averaged a little better than fall plowing for all crops except wheat where both practices show the same average. Studying the results from the standpoint of station averages, it will be observed that fall plowing has given better results in four instances, namely at Dickinson (1) with wheat, at Edgeley with oats and at Williston with barley and with corn. The results from year to year are not consistently in favor of either practice. Taking the total number of station years when results are obtained, it may be noted that in nearly sixty per cent of the tests, spring plowed land produced the higher yields.

It may be concluded from these results that time of plowing may be adjusted to suit the convenience of the farmer and the amount of moisture in the soil.

DISKING VERSUS PLOWING CORN GROUND

Some of the experiments afford a chance to compare disking with plowing corn ground as a means of preparing it for both wheat and oats. The results are presented in Table No. XVI. It shows but slight differences in the average yields of wheat produced by the two methods. In some years one practice gives slightly better yields while in other seasons conditions are reversed. Similar results have been secured with oats, except at Dickinson where

1. In connection with the Dickinson results, it is well to note that the 1912 crops were destroyed by hail. As a result, fall plowing was done earlier than usual, while the land to be spring plowed in 1913 supported partly recovered crops and a considerable growth of weeds during the remainder of the season. No doubt this will explain why the Dickinson results for 1912 are so decidedly in favor of fall plowing.

corn stubble when disked has given an average of 8.2 bushels more than when plowed.

At none of the stations is the advantage in favor of plowing corn land sufficient to pay for the extra cost of plowing. The results obtained thus far indicate that disking corn land is a practice well adapted to the greater portion of North Dakota.

HARROWING.

Probably no implement is more commonly or widely used for mulching than is the ordinary spike-tooth harrow. By its use the surface is pulverized and leveled, and weeds just starting are killed. It may be used when plants attain a height of several inches and, in the case of corn and potatoes, this will save considerable cultivation. But, unless there are weeds to be killed, or the soil is lumpy or cracking, there is little to be gained by harrowing.

WEEDING

In some localities the weeder is highly recommended as a substitute for the harrow, but from what little data we have at hand, there is nothing to indicate that its value for tillage justifies its initial cost or even the cost of operation.

CULTIVATION

For cultivated crops it is evident that the use of the cultivator is usually not necessary until the plants are too high for harrowing and then primarily for weed destruction. From experiments carried on at a number of stations in regard to corn cultivation, it was concluded that cultivation of corn was of very little avail, except to kill weeds. Corn yields were practically as high where the weeds were kept down by being clipped off with the hoe as they were when it was well cultivated. It appears then that very little is to be gained by cultivation so long as sufficient mulch is retained to prevent baking and cracking, or unless there are weeds to be killed.

GENERAL DISCUSSION

This bulletin presents some of the results of work in crop rotation and cultivation methods that was started in 1906 at Edgeley, in 1907 at Dickinson, in 1909 at Williston, and in 1911 at Hettinger. It has been continued without break at each place since it was started.

Climatic conditions are the chief determining factors in crop production in this section. Of these the most important are the amount, distribution and character of the rainfall, the amount and intensity of evaporation, and for some crops the length of the frost-free period. The problem of the farmer is how to make the most efficient use of the limited supply of water in converting the fertility of the soil into profitable products. A study of the work in hand shows a marked general relation between the amount of precipitation during the growing season and the average yield of crops from all methods. This relationship is much closer than that between

annual precipitation and yields. From all available records it appears that the average length of the frost-free period has been 129 days at Edgeley, 119 days at Williston, and 110 days at Dickinson. The record at Hettinger is far too short a period to be comparable with that of the other stations. The uncertainty of the length of the period between frosts which is shown in detail in Figure No. 9 is as important a factor in determining the choice of crops and varieties as is the average length of the period.

The absence of an underground supply of water such as a water table common in more humid sections is a distinguishing feature of soil conditions in western North Dakota. On land that is cropped every year the rainfall seldom penetrates below the fourth or fifth foot and is generally all removed by the crop. When land is fallowed in seasons of heavy precipitation, moisture has been stored at Dickinson and Williston to the depth of eight to nine feet. Popular belief has generally overestimated the percentage of the total rainfall that can be stored by even the most intensive methods. Extensive studies made in connection with this work have shown that even in systems of alternate cropping it has not been possible to store in the soil more than one-third of the rain that fell during the fallow period. It has also been shown that stored moisture alone, unaided by fairly seasonal rainfall, has not been able to mature a crop.

Crops on shallow soil such as the work is located on at Edgeley are much more dependent upon rain that falls while they are growing than are crops on deeper soils of greater capacity for the storage of available water such as the soil at Dickinson. Cultivation is of much greater importance in preventing the growth of weeds than it is in maintaining a soil mulch.

The average annual yields show the relatively great importance of seasonal conditions in determining production. They also show the relative safety of production of a crop of corn fodder. Comparison of the yields following summer tillage and those following a grain crop shows that at none of the stations except Dickinson is there any marked increase in favor of the summer tillage except in dry years. From the standpoint of average production in a series of years it is of doubtful value as a general practice in western North Dakota. It may have a temporary place as a partial insurance against crop failure in the more unfavorable years.

A comparison of the yields following corn and those following fallow indicates that fallow has little advantage over corn as a preparation for the growth of spring grains in North Dakota. The realization of the value of the corn crop in North Dakota is dependent upon its utilization as feed. The development of livestock industry and the growth of corn for feed will insure practically a good return of grain and will put agriculture upon a much more stable and remunerative basis than will the general use of fallow as a unit in a grain growing system. Green manuring with either rye, field peas or clover has not produced results favoring the practice.

The use of barnyard manure in connection with fallow has increased the yield over that from land fallowed without manure. The effect of the manure has been exhibited in increased yields for at least three years following its application.

While some of the sod crops are valuable in themselves, the crops that follow when they are broken are generally decreased in yield. This indicates that sod crops should not enter into short rotations in this section. The small grains generally yield higher after corn than after small grain. They generally yield higher after one of the other small grains than they do after themselves. The differences in the relative yields following fall and spring plowing are largely determined by the season. On the whole there is so little average difference as to indicate that time of plowing may be adjusted to suit the convenience of the farmer except as it may be determined by the amount of moisture in the soil.

Disking corn stubble that has been kept free from weeds has proven to be fully as good a preparation as plowing it. At none of the stations has the advantage in favor of plowing it been sufficient to pay for the extra cost of plowing.

CONCLUSIONS.

1. Climatic conditions are the chief determining factors in crop production in western North Dakota.
2. The amount of rainfall during the growing season is a better criterion of crop production than is the annual rainfall.
3. Available records show the average frost-free period to be 129 days at Edgeley, 119 days at Williston, and 110 days at Dickinson.
4. Even with alternate cropping, water is seldom stored to a greater depth than that from which annual crops can recover it.
5. While stored water may be of value in supplementing rainfall, it is unable in itself to mature a crop in western North Dakota.
6. Shallow soils are not as responsive to tillage as are deeper soils.
7. Prevention of the growth of weeds is a much more important function of cultivation than is the maintenance of a mulch.
8. Summer tillage has a certain value as insurance against crop failure. It has not, however, increased average yields over those obtained by other methods enough to warrant giving it more than a secondary and temporary place in the agriculture of this section.
9. The application of barnyard manure has shown marked value.
10. Sod crops should not enter into short rotations.
11. Neither fall nor spring plowing has a marked advantage of one over the other in the average of a series of years.
12. Disking land upon which a crop of corn has been raised, and kept free from weeds, is as good a preparation for the succeeding grain crop as plowing.

MONTHLY AND ANNUAL SEASONAL PRECIPITATION.
1901-1914.
EDGELEY, N. DAK.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Seasonal				
													Apr. 1 to Apr. 1 to				
													Jul. 31	Aug. 31	Sep. 30		
1901	.29	.30	.61	1.00	.15	5.63	5.03	1.05	1.41	2.65	.15	.98	19.25	11.81	12.86	14.27	
1902	.21	.57	6.25	2.47	3.94	5.90	1.56	4.84	.95	.91	.14	.87	28.61	13.87	18.71	19.66	
1903	.75	1.34	.88	2.85	2.24	1.57	1.93	5.31	3.07	.68	.07	.28	20.97	8.59	13.90	16.97	
1904	.23	.17	1.19	3.30	1.29	5.40	2.79	.42	.78	1.01	.07	.81	17.46	12.78	13.20	13.98	
1905	.15	.17	.79	1.41	4.33	3.48	2.60	1.71	.85	.24	1.46	.00	17.19	11.82	13.53	14.38	
1906	.13	T	.16	1.58	5.59	3.69	3.17	1.56	1.45	.93	1.05	.65	19.96	14.03	15.59	17.04	
1907	.42	.06	.21	.35	2.23	1.76	2.10	1.20	2.79	.82	T	.11	11.94	6.44	7.64	10.43	
1908	.04	.65	1.45	1.26	3.47	3.26	1.19	1.97	1.81	1.34	.63	.20	17.27	9.18	11.15	12.96	
1909	.12	.25	T	.73	4.56	1.97	3.24	1.87	1.00	.99	.34	.84	15.31	10.50	12.37	13.37	
1910	.14	.30	1.20	2.15	.30	1.91	.72	2.21	4.43	.15	.16	.10	13.77	5.08	7.29	11.72	
1911	.27	.35	.03	1.55	2.71	1.22	1.61	4.12	2.92	.67	.20	.41	16.06	7.09	11.21	14.13	
1912	.48	.01	.08	2.71	3.23	3.82	5.87	2.72	2.47	.18	T	.28	21.95	15.73	18.45	20.92	
1913	.31	.04	.24	1.46	1.44	3.98	2.65	3.74	2.90	3.37	.28	.25	20.66	9.53	13.27	16.17	
1914	.13	.20	.57	4.88	1.80	4.00	2.55	1.97	.80	.92	.10	.13	18.05	13.23	15.20	16.00	
Av.																	
14 yrs.	.26	.32	.98	1.98	2.66	3.40	2.65	2.48	1.97	1.02	.33	.41	18.46	10.69	13.17	15.14	

1892-1914.

DICKINSON, NORTH DAKOTA.

285

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	Apr.- July	Seasonal Apr.- Aug.	Apr.- Sept.
1892	T	0.60	0.60	3.60	1.77	2.20	3.89	1.62	0.10	0.24	0.15	0.38	15.15	11.46	13.08	13.18
1893	0.26	T	0.60	0.45	2.90	1.45	1.87	0.46	1.59	0.37	0.02	1.06	11.63	6.67	7.13	8.72
1894	0.12	T	0.94	2.40	0.90	3.79	0.23	0.95	0.90	0.58	T	T	10.81	7.32	8.27	9.17
1895	0.10	0.32	1.06	1.36	1.69	3.28	2.47	0.51	0.13	0.00	0.34	0.50	11.76	8.80	9.31	9.44
1896	0.92	0.56	1.01	2.35	5.16	2.54	1.55	0.58	0.30	0.71	2.65	0.15	18.48	11.60	12.18	12.48
1897	1.10	1.20	2.21	1.93	0.73	1.19	1.29	1.77	0.36	0.15	0.85	T	13.18	5.14	6.91	7.27
1898	T	0.20	0.38	1.02	2.00	1.30	1.63	0.77	0.79	2.73	0.30	0.80	11.92	5.95	6.72	7.51
1899	0.12	0.20	0.82	1.83	3.51	2.59	2.79	3.41	0.08	1.43	0.22	0.27	17.27	10.72	14.13	14.21
1900	0.21	0.63	0.96	0.65	0.48	0.83	1.19	3.15	2.56	0.47	0.55	0.10	11.78	3.15	6.30	8.86
1901	0.01	0.39	0.70	0.62	3.02	3.83	3.69	0.45	0.83	0.22	0.80	1.25	12.92	8.27	8.72	9.55
1902	0.18	1.43	2.64	0.16	3.02	2.56	2.26	1.40	0.16	0.49	0.35	0.64	15.65	8.36	9.76	9.92
1903	0.85	0.43	T	0.31	3.59	1.18	0.52	5.52	3.70	0.08	0.13	0.82	17.13	5.60	11.12	14.82
1904	0.33	0.60	2.02	0.92	0.90	6.10	0.32	2.68	0.26	0.22	0.04	0.80	15.19	8.24	10.92	11.18
1905	0.23	0.49	0.15	0.09	2.74	3.75	3.46	1.48	2.03	0.71	1.31	0.08	16.55	10.04	11.52	13.58
1906	0.65	0.40	0.98	1.10	7.11	5.40	0.16	2.64	0.25	0.14	0.87	0.76	20.46	13.77	16.41	16.66
*1907	0.80	0.14	0.39	0.30	1.33	2.63	4.82	1.93	1.22	0.04	0.02	0.22	13.94	9.18	11.11	12.33
*1908	0.28	0.73	1.42	1.27	3.79	4.05	1.34	1.36	1.55	2.49	0.78	0.24	19.31	10.46	11.82	13.37
*1909	0.27	0.52	0.25	0.60	6.04	3.02	1.87	5.54	0.72	1.03	0.29	1.02	21.22	11.53	17.07	17.79
*1910	0.34	0.97	0.86	1.71	1.26	3.03	2.35	1.48	0.49	0.54	0.15	0.15	13.33	8.35	9.83	10.32
*1911	0.90	0.55	0.43	0.48	1.63	2.61	1.29	1.69	2.53	2.09	0.56	0.22	14.98	6.01	7.70	10.23
*1912	0.41	0.12	0.50	2.51	3.99	2.06	3.90	2.71	1.81	1.15	0.18	T	19.34	12.46	15.17	16.98
*1913	0.13	0.04	1.22	0.59	1.63	1.83	1.26	2.79	0.97	1.04	0.43	T	11.93	5.31	8.10	9.07
*1914	0.04	0.43	1.27	0.80	2.60	7.60	5.27	2.20	1.21	0.42	0.25	0.29	22.38	16.27	18.47	19.68
Av.																
23 yrs.	0.40	0.48	0.94	1.18	2.57	3.01	2.17	2.05	1.07	0.78	0.49	0.42	15.48	8.90	10.94	12.04

NOTE: * Observations from April to September, inclusive, were taken from records of the Office of Biophysical Investigations, Department of Agriculture.

T indicates a trace of precipitation or less than 0.01 inches.

MONTHLY, ANNUAL AND SEASONAL PRECIPITATION. 1879-1914. WILLISTON- N. D.

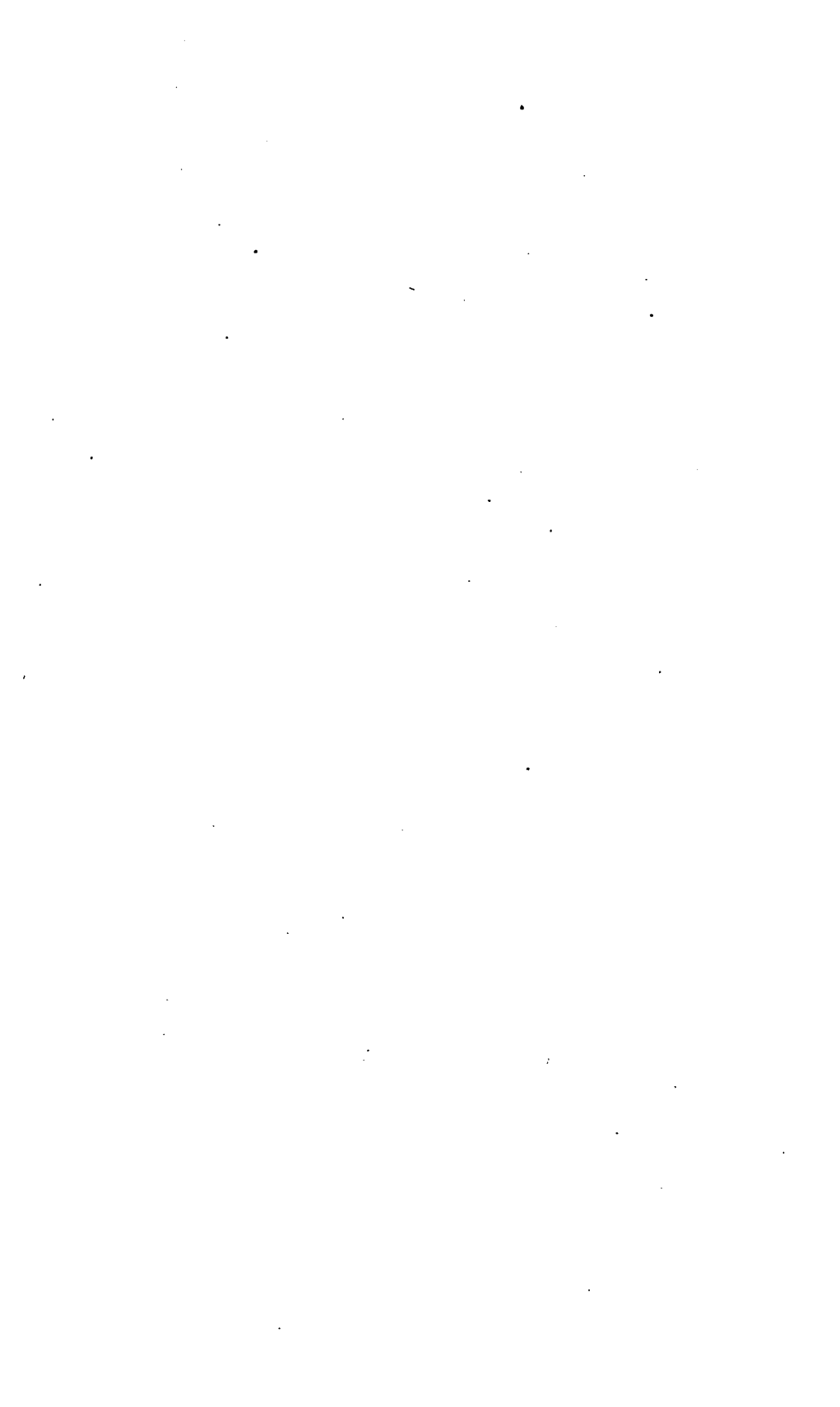
Year	Seasonal																
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Annual	Apr.- July.	Apr.- Aug.	Apr.- Sept	
1879	58	59	03	2.75	5.56	3.35	3.63	18	T	1.55	37	1.68	20.27	15.29	15.47	15.47	
1880	10	51	21	.74	4.02	5.46	4.17	2.36	1.04	.90	.66	3.08	23.25	14.39	16.75	17.79	
1881	1.98	1.10	1.17	1.34	1.00	3.45	1.22	1.10	.58	.39	.39	.09	13.81	7.01	8.11	8.69	
1882	26	29	69	.94	1.61	1.87	2.25	1.6	2.86	1.00	.29	.51	12.73	6.67	6.83	6.69	
1883	1.98	36	91	.48	.59	.97	1.69	1.96	.22	1.41	.14	.11	10.82	3.73	5.69	5.91	
1884	11	12	10	1.30	1.14	.99	1.87	1.06	.53	.44	.31	.40	7.37	4.30	5.36	5.89	
1885	64	44	03	1.71	1.02	6.05	3.02	1.50	.26	.19	.56	.14	15.56	11.80	13.30	13.56	
1886	41	71	31	2.25	1.14	.93	.56	.87	.05	1.57	.59	.55	10.24	4.88	5.75	5.80	
1887	51	18	12	1.09	1.59	3.25	2.00	8.91	1.07	1.43	.10	.18	15.43	7.93	11.84	12.91	
1888	47	33	44	.61	.96	6.75	2.12	1.61	.62	.63	.10	.07	14.70	10.44	12.05	12.67	
1889	13	30	20	.60	2.69	1.03	.63	.95	1.13	.01	.37	.42	8.46	4.95	5.90	7.03	
1890	22	18	58	.60	1.58	5.23	1.06	.22	2.05	2.45	.03	.04	14.24	8.47	8.69	10.74	
1891	19	14	27	1.84	1.49	7.08	2.99	.78	.66	1.96	1.44	.14	18.98	13.40	14.18	14.84	
1892	14	38	38	2.65	.48	2.41	4.49	.62	.11	.15	1.12	1.33	14.26	10.08	10.65	10.76	
1893	2.04	31	12	.38	4.79	1.84	1.85	.81	.64	1.14	.56	1.92	15.90	8.86	9.17	9.81	
1894	88	20	2.23	2.07	3.15	4.68	.02	.73	1.50	1.05	.85	.40	17.76	9.92	10.65	12.15	
1895	53	47	.07	2.52	3.02	3.67	2.55	1.03	.32	.35	1.91	.63	17.07	11.76	12.79	13.11	
1896	2.02	71	1.80	2.86	5.79	3.45	1.22	.72	.89	.34	2.10	.14	22.04	13.32	14.04	14.93	
1897	56	1.10	2.10	1.17	.72	2.71	1.36	.45	.58	.43	.85	.16	12.19	5.96	6.41	6.99	
1898	01	74	1.25	1.08	1.21	4.56	1.93	.23	.99	2.08	.30	.06	14.44	8.78	9.01	10.00	
1899	58	10	79	.60	2.39	3.72	1.91	.56	.01	1.06	.13	.76	12.61	8.62	9.18	9.19	
1900	85	.85	1.25	.57	1.46	.65	2.34	4.47	2.24	1.03	.71	.21	15.81	5.02	9.49	11.73	
1901	64	34	26	.46	.71	8.84	2.71	.74	1.77	1.4	1.02	.83	18.36	12.72	13.46	15.23	
1902	09	152	1.36	.53	2.69	3.92	3.43	1.26	.33	.32	.72	.68	16.85	10.57	11.83	12.16	
1903	40	27	.09	.79	3.94	2.06	2.43	5.02	1.39	.05	.18	1.07	17.69	9.22	14.24	15.63	
1904	58	59	1.57	.78	1.27	2.53	.56	.57	.12	.23	.01	.58	9.44	5.19	5.76	5.88	
1905	10	14	18	.04	1.74	3.44	1.94	.74	1.93	.06	.31	.04	10.66	7.16	7.90	9.83	
1906	82	03	16	1.59	4.55	8.80	.50	2.39	1.98	.26	1.00	.73	22.01	15.44	17.83	19.01	
1907	1.03	13	.66	.53	1.11	2.03	1.82	2.06	.45	.08	.00	.26	10.18	5.49	7.55	8.00	
1908	04	39	.79	1.96	1.80	2.64	.60	1.11	2.18	1.18	.16	.01	13.49	7.00	8.11	10.29	
1909	31	10	12	.64	2.84	3.72	1.72	.38	1.27	.17	.20	.46	11.93	8.92	9.80	10.57	
1910	27	34	1.23	1.40	1.30	1.65	1.27	1.69	.14	.05	.66	.28	10.28	5.62	7.31	7.45	
1911	56	34	42	.32	3.00	1.37	1.40	2.56	2.49	.53	1.25	.59	14.83	6.09	8.65	11.14	
1912	44	17	35	2.13	4.59	1.59	3.60	3.47	1.21	1.12	.14	.18	18.99	11.91	15.38	16.59	
1913	52	14	.94	.15	1.06	2.15	2.60	5.50	1.13	.94	.15	.14	16.27	5.96	11.45	12.58	
1914	55	28	.50	.49	1.21	7.98	2.32	3.55	.64	.38	.24	.33	18.47	12.00	15.55	16.19	

Year	Seasonal															
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual	Apr.- July	Apr.- Aug.	Apr.- Sept.
1894	0.12	T	1.86	2.40	1.74	3.10	0.45	0.95	0.90	0.58	T	0.20	12.30	7.69	8.64	9.54
1895	0.26	0.70	0.05	0.70	2.30	2.80	1.90	0.00	0.13	0.09	1.10	0.50	10.44	7.70	7.70	7.83
1896	0.92	0.30	0.92	0.63	6.00	3.40	1.90	0.20	0.20	0.00	2.80	0.10	17.37	11.93	12.13	12.33
1897	1.00	1.40	1.90	1.17	0.12	1.20	1.60	0.60	0.54	0.20	0.30	0.30	10.33	4.09	4.69	5.23
1898	0.20	0.90	1.14	3.10	1.59	1.20	2.55	0.50	0.75	1.81	0.25	0.20	14.19	8.44	8.94	9.69
1899	0.15	0.50	0.70	2.00	2.50	1.40	2.79	3.41	0.08	1.43	0.22	0.10	15.28	8.69	9.10	9.18
1900	0.23	0.63	0.96	0.30	1.31	1.83	1.19	3.15	2.56	0.47	0.55	0.10	12.28	8.63	8.78	6.34
1901	0.01	0.39	0.70	T	0.06	5.36	2.75	1.15	1.95	0.18	0.20	0.90	13.65	8.17	9.32	11.27
1902	T	1.43	1.33	0.16	2.63	1.09	0.08	1.90	0.35	0.75	0.15	0.53	10.36	3.92	5.82	6.17
1903	0.25	0.50	0.20	0.55	3.92	1.25	1.70	3.90	2.60	T	0.25	0.70	15.82	7.42	11.82	18.92
1904	0.45	0.80	1.40	0.82	1.40	4.20	0.10	2.68	0.60	T	T	0.90	12.85	6.02	8.70	9.50
1905	0.23	0.49	0.15	0.09	1.37	3.97	4.65	2.10	1.55	0.36	1.31	0.35	17.12	10.58	12.63	14.23
1906	0.60	0.80	0.20	1.24	7.11	0.70	0.20	3.00	0.01	0.14	0.87	0.76	15.63	9.25	12.25	12.26
1907	1.30	0.14	0.30	0.30	1.35	2.70	3.20	0.20	1.00	0.14	T	0.10	10.69	7.56	7.75	8.76
1908	0.30	1.30	1.90	2.20	0.56	2.92	1.00	0.67	2.46	2.46	0.32	0.30	16.39	6.68	7.35	9.81
1909	0.47	0.50	0.30	0.37	2.81	3.85	2.78	5.85	2.04	0.67	0.90	0.00	20.04	9.81	15.16	17.20
1910	0.00	1.40	0.75	0.25	0.65	2.65	T	0.91	0.90	0.40	0.00	0.00	8.00	3.55	4.46	6.78
1911	0.20	0.01	0.16	0.57	0.44	1.19	0.28	2.33	1.97	0.55	0.40	0.40	8.50	2.48	4.81	6.78
1912	0.47	0.20	0.20	1.32	2.90	1.25	4.90	1.10	2.45	0.95	T	0.01	15.75	10.37	11.47	18.92
1913	T	0.00	0.24	0.26	2.37	3.93	2.26	1.14	1.59	1.61	0.20	0.02	13.62	8.82	9.96	11.55
Av.	0.36	0.62	0.77	0.90	2.18	2.45	1.81	1.76	1.22	0.63	0.49	0.37	13.53	7.33	8.80	10.05
20yrs.																

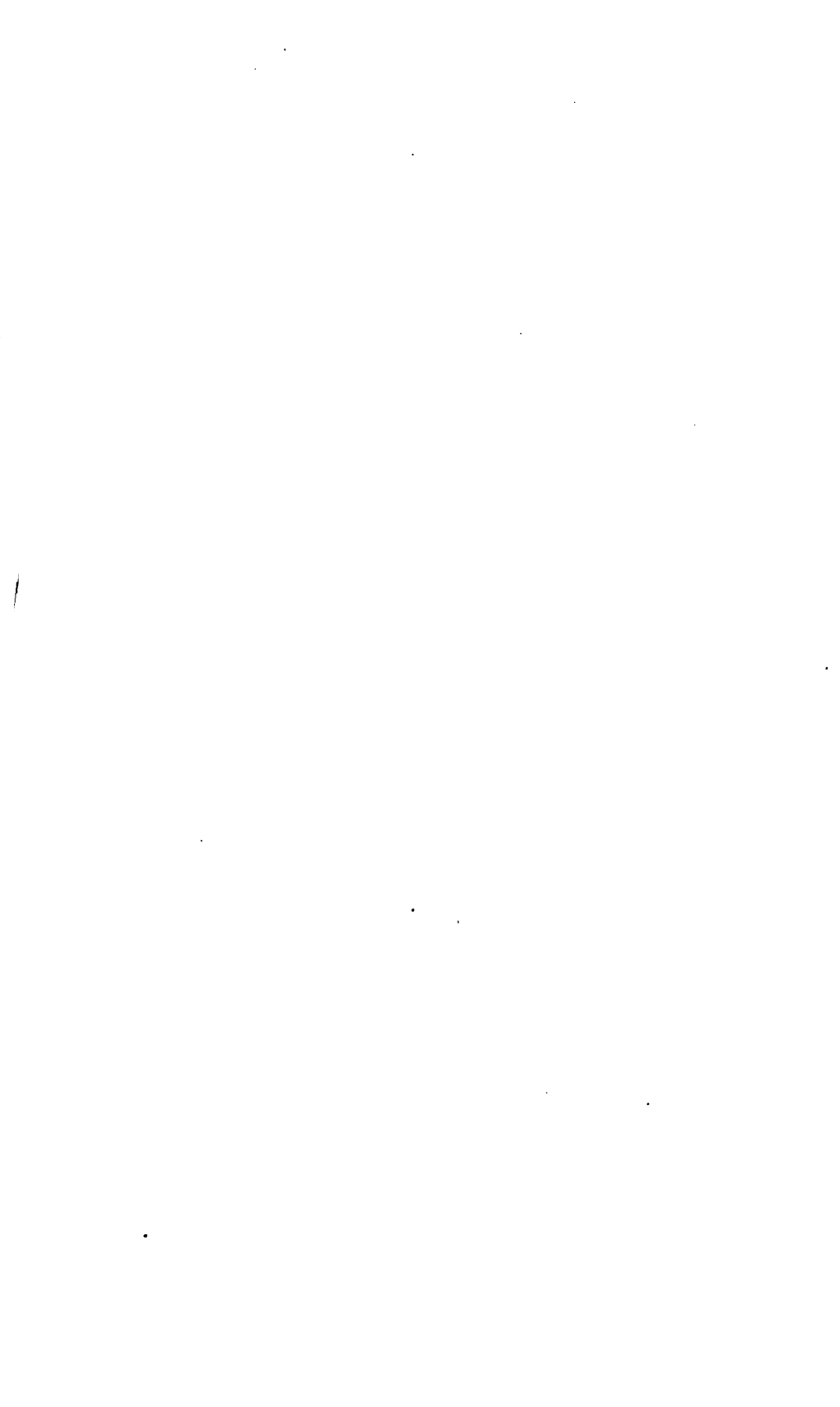
The last three years records were taken from Hettinger. Complete record for 1914 unavailable.











APR 21 1924

North Dakota
Agricultural Experiment Station

Tomatoes for North Dakota

By H. O. Werner

Bulletin No. 111

Agricultural College, North Dakota

MARCH, 1915

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TOMATOES FOR NORTH DAKOTA

(A) PRELIMINARY REPORT ON SOME TOMATO EXPERIMENTS

And

(B) SOME GENERAL INFORMATION ON TOMATO GROWING

By H. O. Werner.

Tomatoes can very easily be produced in North Dakota if a few cultural principles are observed and the proper varieties planted. During the past season the North Dakota Experiment Station has carried on a number of experiments with tomatoes in which the plants were handled in different ways. During the season a rather complete variety and strain test of tomatoes was conducted. In this trial, eighty-seven different varieties, comprising one hundred and twenty-two strains of tomatoes, were used. In this publication a report of the results of the first year's work is given, together with other information on the growing of tomatoes.

The tomato, being of tropical origin, requires a high temperature, a large amount of sunshine and a long growing season. As it is very easily injured by cold, the outdoor season for growing tomatoes lies between the dates of the last spring frost and the first frost in autumn, which in this vicinity is usually from May 20th to September 15th.

The earliest tomatoes are produced on rather light, warm, sandy soils, while the largest yields, as well as the largest and most solid tomatoes, are generally produced on the heavier soils. The soil should not have an excessive amount of available nitrogen or there will be danger of causing too much vine growth at the expense of fruit production. On this account, when used directly for a tomato crop, manure should be well rotted and not applied too heavily.

DETAILS OF CULTURAL EXPERIMENTS

In the cultural experiment, twenty plants were used in each plot. Ten of these plants were of the Adirondack Earliana variety, and the other ten plants were of the Bonny Best variety. The rows were 4.5 feet apart and the plants 3.5 feet apart in the rows, giving 2760 plants per acre.

The soil used is of the Fargo Clay type, which is a heavy black surface soil with a sub-soil generally of the same color and texture, but sometimes of a drab color at a depth of 20 to 40 inches. The plot is nearly level, but the soil is well drained. All soil conditions are so uniform that ten plants to a plot give practically as good results as larger sized plots would do.

Except where otherwise stated in these tests, the seed was sown March 26th in the greenhouse, the plants were transplanted to flats in three week and three weeks after that shifted to 3.5 inch clay pots in which they were held until set in the field on May 20th.

PLANTING DISTANCES.

On rich, heavy soils the standard varieties of tomatoes are planted four feet by four feet or five feet by five feet. On poorer soils the plants should be set more thickly. The dwarf varieties can be planted three feet apart, in rows four feet apart.

DATE OF SOWING SEED.

Under favorable conditions the earliest varieties of tomatoes require 100 days from the time the seed is sown until the first ripe fruit is produced. In this strain test of the Earliana the first ripe tomatoes were harvested on July 14th—110 days from the date the seed was sown.

With these strains it was found that the largest tomatoes were produced between August 3rd and August 14th or 130 to 140 days from the time the seed was sown. The average weight per fruit gradually increased until that time and then gradually but evenly decreased. The average weight per fruit when at the maximum size was generally about 30 per cent greater than the average weight per fruit for the entire season.

It was further found that the various strains of Earliana did not produce their maximum amount of marketable tomatoes per day until September 8th to 15th, or in other words, they did not reach their maximum yielding capacity until 165 to 175 days from the date the seed was sown. In Table I is shown the average amount of marketable fruit ripened per plant per day, through the entire season by each of the eleven strains of Earliana. The figures given are in grams of fruit per plant. One pound is equal to 450 grams. (For the names and sources of the various strains see Table VIII.) From Table I it will be noticed that six of the strains gave their maximum yield by September 8th and the other five by September 15th. The drop in the yield of most of the strains during the latter part of August was due to a prolonged spell of cool, wet, cloudy weather that was very unfavorable to tomato production.

TABLE I.—AVERAGE WEIGHT OF MARKETABLE FRUIT RIPENING PER DAY PER PLANT.

Rec. No.	Time of Season.									
	July 23	July 28	Aug. 3	Aug. 7	Aug. 14	Aug. 20	Aug. 31	Sept. 8	Sept. 16	Sept 22
1	13	15	60.	186.	198.3	287.6	147.2	433.5	278.4	148.6
2	18.2	1.7	59.1	149.3	177.9	190.3	132.9	338.2	192.3	183.1
3	19.8	3.7	27.	175.6	172.5	157.6	136.	310.1	255.9	185.7
4	18.	2.6	48.6	134.4	185.3	104.2	133.9	284.6	253.1	136.1
5	7.1		7.7	95.	141.9	95.9	109.6	286.8	212.3	142.5
6	7.6		14.2	88.6	140.9	135.7	109.4	292.6	465.4	188.3
7	13.3	3.3	26.3	77.5	134.8	91.4	70.7	248.3	254.	149.
8	17.4	5.3	54.7	161.3	148.2	112.4	108.4	276.5	350.	217.1
9	31.6	1.7	43.7	77.9	159.7	158.	143.9	273.4	421.8	176.4
10	13.9		12.9	111.	164.5	137.3	120.4	321.7	355.6	155.5
11	5.7		7.4	121.	149.1	137.3	109.6	366.2	271.2	153.9

The dates for the first ripe fruit, maximum size and maximum yield given for the Earliana are about the same as were secured for the June Pink, while the ripening dates for the Bonny Best are a few days later. The Chalk's Jewel attains the same degree of ripeness about ten days later than the Earliana. Many varieties did not reach their maximum yield because of their requiring too long a season.

A short growing season may be lengthened by sowing the tomato seed indoors or under glass before the plants can be set in the field. The best glass structure for the farmer is a manure hot bed, (described in circular No. 5 of this station.)

From the experimental results shown in Table II it may be seen that in both varieties prior to August 20th the most tomatoes were

TABLE II.—DATE OF SOWING SEED.

Plot No.	Treatment	Marketable Fruit Per Plant.				Per ct of fruit Market able
		Weight to Aug 20	Total Weight	No. of Fruits	Ave. Wt Per fruit	
EARLIANA						
9	Seed Sown Feb. 27	1.45 lb.	20. lb.	72.8	4.39 oz.	93.5
2	" " March 6	2.12 "	21.9 "	90.8	3.86 "	90.
10	Seed Sown March 16	1.85 "	26.3 "	92.8	4.53 "	92.2
6	" " March 26	2.05 "	29.2 "	107.6	4.34 "	93.9
11	" " April 6	2.49 "	19.1 "	70.4	4.35 "	92.5
12	Seed Sown April 16, Set to field June 1	1.11 "	26.0 "	90.2	4.61 "	93.7
13	Seed Sown in cold Frame Apr. 16. Set to field June 13	.05 "	8.9 "	27.5	5.20 "	98.
14	Seed sown in field May 21	.06 "	11.4	39.	4.67 "	93.7
BONNY BEST						
9	Seed Sown Feb. 27.	.13 lb	9.2 lb.	28.4	5.0 oz.	85.1
2	" " March 6.	.88 "	13.5 "	38.8	6.37 "	87.6
10	Seed Sown March 16.	.04 "	15.6 "	38.7	6.44 "	93.6
6	" " March 26.	.45 "	18.7 "	54.4	5.5 "	94.7
11	" " April 6.	.9 "	16.8 "	57.	4.7 "	91.2
12	Seed Sown April 16, Set to field June 1	.38 "	8.4 "	22.7	5.91 "	96.7
13	Seed Sown in cold Frame Apr. 16. Set to field June 16	0	3.1 "	9.1	5.45 "	97.3

produced, on the plants started April 6th (plot 11) followed by those started March 6th (plot 2) while next in order were those of March 26th (plot 6). In both varieties the total yield was lowest from the plants started in the cold frames the middle of April (plot 13) and set in the field the middle of June. These plants were checked when small because of the low temperature at which they were started. Plants sown on the same date but given better conditions in plot 12 in the greenhouse gave decidedly better results. Seed sown in the open ground on the 21st of May gave a profitable yield when the Earliana variety was used. On account of the long, warm, sunny days just after May 21st this plot produced some fruit in 91

days, but did not have time to reach its maximum yield. In a long season such as that of 1914, growing tomatoes in this way would be profitable, but as the average season is at least ten days shorter the practice of the field sowing of the seed is not recommended. The lower yields from the plants of the earlier sowings, are due to the plants having become too large to be transplanted without receiving a serious check in their growth. The Bonny Best, being a later variety seems to do slightly better when sown early than does the Earliana. These results indicate that the last week in March is the best time for sowing tomato seed in North Dakota.

METHODS OF RAISING PLANTS.

For sometime the standard method of raising tomato plants for the earliest fruit, has been to sow the seed early and transplant several times, making the final planting in earth or paper pots as described in this article. Dirt bands have become very popular for raising early plants. These dirt bands are strips of wood or paper, constructed in the form of bottomless cubes or cylinders. They are filled with soil and several seeds are sown in each dirt band. Later all but one of the plants in each band are pulled up. The plants are not transplanted until they are ready to set in the field. This system of raising tomato plants has generally produced the earliest tomatoes. The results obtained at this station are shown in Table III. It is seen

TABLE III.—METHOD OF RAISING PLANTS.

Plot No.	Treatment.	Marketable Fruit Per Plant				Per ct of fruit marketable
		Wt. to Aug. 20	Total Weight	No. of fruits	Ave. Wt per fruit	
EARLIANA						
22	Plants Not Transplanted					
23	Seed Sown in 4 in. pots	1.41 lb	20.9 lb.	88	3.80 oz.	91.9
23	Seed Sown in Dirt Bands	3.49 "	26.7 "	100	4.28 "	91.5
24	Seed Sown in Flats and thinned	.63 "	28.9 "	94	4.91 "	93.2
	Plants Transplanted Once					
25	To Flats, 2 in. apart	.31 "	20.5 "	68	4.74 "	94.6
	Plants Transplanted Twice.					
26	Last to Paper Pots.	2.13 "	29.9 "	99	4.84 "	91.9
27	Last to Flats (4 in. apart.)	1.05 "	27.0 "	100	4.32 "	93.3
28	Last to Tin cans.	2.60 "	27.5 "	106	4.17 "	91.5
6	Last to Earth Pots.	2.05 "	29.2 "	108	4.34 "	93.9
BONNY BEST.						
22	Plants Not Transplanted					
23	Seed Sown in 4 in. pots	.95 lb	19.8 lb.	61	5.15 oz	91.8
23	Seed Sown in Dirt Band.	1.57 "	20.1 "	64	5.42 "	93.3
24	Seed Sown in flats and thinned	.50 "	17.7 "	53	5.34 "	91.
	Plants Transplanted Once.					
25	To Flats, 2 in. apart	.59 "	15.2 "	42	5.90 "	91.9
	Plants Transplanted Twice					
26	Last to Paper Pots.	.32 "	17.8 "	51	5.64 "	98.
27	Flats (4 in. apart.)	.66 "	17.4 "	57	4.90 "	94.7
28	" " Tin Cans.	1.56 "	21.7 "	68	5.12 "	94.6
6	" " Earth Pots.	.45 "	18.7 "	54	5.50 "	94.7

here that in both varieties the most early tomatoes were gotten from the plants raised in dirt bands (plot 23). Next to this in point of earliness came the plot in which the tomato plants were transplanted twice with the final shift in the regular No. 3 (2 lb.) tomatoe cans. The plants raised by these two methods had more soil available for root development than the plants of the other plots and when moved to the field their root systems were not disturbed at all. The early fruiting tendency of these plots was probably due to the fact that when set in the field the plants had a strong root system and were in a position to develop fruit buds earlier than the plants in the other plots. The low yield of fruit prior to August 20th in plot 24 (seed sown in flats and thinned) and plot 25 (transplanted once to flats) is accounted for by these plants having been weak and spindly, because of a lack of sufficient space for the tops to develop and also to an unavoidable breaking up of the root system when transplanting the plants. Of all the plots in this series, the most stocky plants were those raised in dirt bands and tin cans. In comparing total yields of the two varieties the results do not agree exactly. The tendency of the Earliana seems to have been to produce more fruit on the plants that were transplanted twice (plots 6, 26, 27, 28) while the Bonny Best produced slightly more fruit on the plants not transplanted at all (plots 22, 23, 24.) This was probably because the several transplantings caused slight checks in the growth of the plants from which the Bonny Best, being a later variety, did not recover as thoroughly as the Earliana. With both varieties one transplanting with plants 2 inches apart proved the poorest method. Comparing the different devices into which plants are transplanted, no appreciable differences appear between paper pots, earthpots and tin cans. The plants given two transplantings, the final one into flats, produced a small amount of fruit up to August 20th,—probably because of their root system having been disturbed when set in the field. For very early tomatoes and for heavy yields per plant in the home garden the waste tin cans and cheap dirt bands can be used to produce high grade tomato plants most economically.

DATE OF TRANSPLANTING TO THE FIELD.

With both varieties the tendency to produce early fruit on plants started on March 6th and transplanted on May 13th, was noted. See Table IV plot 1. The May 20th transplantings (plots 2 and 6) were next in earliness. Plants started March 26th and transplanted May 20th (plot 6) proved the heaviest total producers. The early sown seed and early transplanted plants gave the earliest tomatoes. Unless frost protection can be given no tomato plants should be set out before May 20th. Frost protection can be given by putting plant forcers (small boxes with glass tops) over the plants, or if frost is expected cover the plants with a paper sack or lay the plants down and cover them with earth. The latter is the method that was used to protect the plants in plots 1 and 2, from several hard frosts. The plants were all very much over size by June 1st and 12th, and received very serious checks when transplanted, which accounts

TABLE IV.—DATE OF TRANSPLANTING.

Plot No	Treatment	Marketable Fruit Per Plant				Per ct. of fruit marketable
		Wt.to Aug.20	Total Weight	No.of fruits	Ave.Wt. per fruit	
EARLIANA						
	Seed Sown March 6					
1	Transplanted May 13.	3.50 lb	16.8 lb.	79	3.42 oz.	87.
2	" May 20.	2.12 "	21.9 "	91	3.86 "	90
3	" June 1	.79 "	15.8 "	69	3.65 "	93.5
4	" June 12.	.50 "	15.3 "	80	3.46 "	93.3
	Seed Sown March 26					
5	Transplanted May 13.	1.79 "	17.1 "	63	4.31 "	90.5
6	" May 20	2.05 "	29.2 "	108	4.34 "	93.9
7	" June 1.	1.00 "	21.2	81	4.17 "	94.2
BONNY BEST						
	Seed Sown March 6					
1	Transplanted May 13.	.93 lb	14.8 lb.	54	4.4 oz.	88.6
2	" May 20	.86 "	13.4 "	34	6.35 "	95.4
3	" June 1	.09 "	9.2 "	32	4.53 "	83.8
4	" June 12.	.05 "	10.2 "	27	6.14 "	90.4
	Seed Sown March 26.					
5	Transplanted May 13.	.97 "	16.7 "	53	5.03 "	93.9
6	" May 20.	.45 "	18.7 "	54	5.50 "	94.7
7	" June 1.	.23 "	13.9 "	43	5.15 "	91.7

for their inferior production. From Table IV we notice that in both varieties the tendency was to produce larger fruit on the plants started at the later date. This same tendency is to some extent shown in Table III.

METHOD OF TRANSPLANTING.

In moving the plants to the field, they should be set several inches more deeply than they were growing in the pots or flats. If the plants have grown to be long and spindling the roots should be set as deeply as convenient and a slight furrow made away from the hole dug for the plant, along which the stalk of the plant is placed and then covered with ground until only the top two or three inches are left uncovered. Roots will then be produced all along this buried stem. When transplanting tomatoes it is a good plan to remove the lower leaves and trim some of the larger leaves to avoid excessive transpiration. An ordinary garden spade is about the most useful tool for making the holes. If a large area of tomatoes is to be set out, the field can be marked off by plowing furrows across the field both ways and setting the plants at the intersections. The effect of not planting deeply enough is shown in the results obtained from plot 15 (Table V) in which the plants were set merely as deep as they had been growing in the pots. In both varieties the results show later fruit production, a smaller total yield and fewer and smaller fruits than from plot 6 in which the plants were set deeply.

TABLE V.—FIELD TREATMENT AT PLANTING TIME.

Plot No.	Treatment	Marketable Fruit Per Plant				Per ct. of fruit market able.
		Wt. to Aug. 20	Total Weight	No. of fruits	Ave. Wt. per fruit	
EARLIANA						
6	Normal treatment, (Deep planting, no manure)	2.05 lb	29.2 "	108	4.34 oz.	98.9
15	Plant only depth of plant in pot	.82 "	22.5 "	88	4.08 "	92.1
17	Manure in Rows	1.65 "	24.5 "	107	3.67 "	91.5
BONNY REST.						
6	Normal treatment. (Deep planting, no manure)	.45 lb	18.7 lb.	54	5.5 oz.	94.7
15	Plant only depth of plant in pot	.44 "	14.5 "	46	5.09 "	92.9
17	Manure in Rows	.22 "	12.2 "	43	4.53 "	90.8

It is not generally considered advisable to add much manure to tomatoes. In these experiments one of the furrows was filled with thoroughly rotted manure and covered with ground and the plants set along this furrow. The result was later first fruits, a reduced total yield, smaller tomatoes and a lower per cent of marketable fruit in both varieties, as compared with the unmanured plot (Table V, plots 17 and 6).

CUT WORMS.

Soon after the tomato plants are set out they are often attacked by cut worms. The cut worms do their damage by cutting the plant off just below the surface of the soil. The plants can be protected from them by wrapping pieces of paper around the stems so that the stems will be protected for about two inches below the surface of the soil and a slight distance above the soil. Another method is to scatter poisoned bran around the plants for the purpose of poisoning the cut worms.

CULTIVATING AND MULCHING.

After the plants have been properly transplanted, they should be cultivated as long as it is possible to get through the rows with a horse, in order that the loss of soil moisture may be reduced to a minimum. In lighter soils,—that dry out during late summer,—much of the soil moisture can be saved by mulching with a coat of manure or straw at the time that cultivation is stopped by the rank growing vines. Many growers train the tomatoes on trellises or stout stakes, thus keeping the vines off the ground and permitting continuous cultivation during the entire summer.

ROOT AND TOP PRUNING.

Our seasons are seldom long enough for even the early varieties of tomatoes to ripen all the fruit they are capable of producing or that the plants set. To see if there are not some methods by which the maximum crop could be produced per plant, experiments were carried on involving root pruning (Table VI) and top pruning (Table VII.)

MARKETABLE EARLY MAT TOMATOES PER PLANT
AT EACH PICKING
FROM
ROOT PRUNED AND UNPRUNED PLANTS

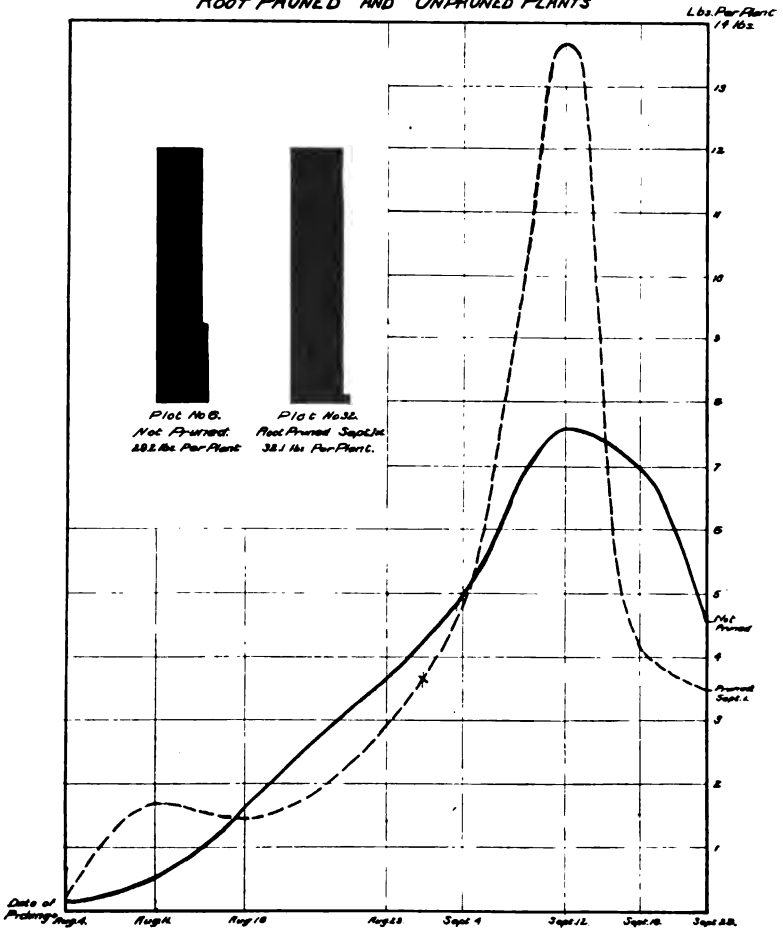


Plate I

ROOT PRUNING.

The roots were pruned by pulling up the plants so as to loosen the main roots and tear up the root system to a considerable extent. This was done on July 23rd, August 17th and September 1st. In both varieties it stimulated early ripening of fruit, as it caused all the fruit that was on the plant to ripen more quickly. The plots pruned at the two earlier dates (plots 20 and 21) produced a smaller total crop than the normal treatment (plot 6). The pruning on September 1st (plot 32) produced a decided increase in total yield over any of the other treatments in the entire experiment. This very high yield is due to the plants having been stimulated, by the pruning, (see plate I) thus ripening practically all of their fruit before the close of the season. The average weight per fruit, is also greater on the plot pruned on September 1st. This seems to indicate that root pruning is very effective if done toward the close of the season so as to stimulate the ripening of all fruit that has already been set.

TABLE VI.—ROOT PRUNING.

Plot No.	Treatment	Marketable Fruit Per Plant				Per ct of fruit mar't-able
		Wt. to Aug. 20	Total weight	No. of fruits	Ave. Wt. per fruit	
EARLIANA.						
20	Pulled Loose July 23	2.15 lb	27.9 lb.	110	4.06 oz.	89.9
21	Pulled Loose Aug. 17	2.73 "	22.3 "	87	4.08 "	89.6
32	" " Sept. 1		32.1 "	114	4.51 "	91.4
6	Not Pruned	2.05 "	29.2 "	108	4.34 "	93.9
BONNY BEST.						
20	Pulled Loose July 23	.40 lb	16.3 lb.	47	5.56 oz.	95.8
21	" " Aug. 17	1.30 "	18.4 "	58	5.07 "	91.3
32	" " Sept. 1		22.8 "	58	6.26 "	94.3
6	Not Pruned	.45 "	18.7 "	54	5.50 "	94.7

TABLE VII.—TOP PRUNING

Plot No.	Treatment	Marketable Fruit Per Plant				Per ct of fruit mar't-able
		Wt. to Aug. 20	Total weight	No. of fruits	Ave. Wt. per fruit	
EARLIANA						
34	Pruned To Fruit Cluster, July 29	2.63 lb	24.8 lb.	98	4.67 oz.	88.8
33	July 29 (Buds nipped)	2.77 "	23.4 "	85	4.43 "	87.2
31	Aug. 17 (Buds nipped)	2.89 "	25.4 "	94	4.30 "	98.4
6	Not Pruned	2.05 "	29.2 "	108	4.34 "	93.9
BONNY BEST						
34	Pruned To Fruit Cluster July 29	.85 lb.	16.7 lb.	41	6.48 oz.	93.8
33	July 29. (Buds nipped.)	.72 "	17.4 "	42	6.63 "	93.6
31	Aug. 17. (Buds nipped.)	.66 "	21.3 "	60	5.64 "	93.4
6	Not Pruned.	.45 "	18.7 "	54	5.50 "	94.7

TOP PRUNING.

The tops were pruned in one plot (34) by clipping off all of the branches to a fruit cluster on the 20th of July. In the other two plots the terminals of all the branches were nipped off.

In both varieties the pruning stimulated early fruit production. In both varieties, in all but one plot (No. 31-Earlana) the pruned plots produced larger fruit than the normal plots. On the other hand, in only one plot (No. 31-Bonny Best) did top pruning result in increased total production. Evidently top pruning is of greatest value in producing larger tomatoes.

USE OF VERY LATE TOMATOES.

In the early fall when one finds that a frost is coming the tomato vines can be covered with canvas or straw and saved, if there are only a few vines. With large areas the plants may be pulled by the roots and hung up in a cool place where they will not freeze, but will be able to ripen most of the fruit on the vines; or the green tomatoes can be picked and placed in a cool place and allowed to ripen or be used green for pickling. Tomatoes carefully put away while green at this time will ripen in from four to eight weeks. They will, however, be of inferior quality as compared with the naturally ripened tomatoes.

VARIETIES OF TOMATOES

During the summer of 1914, 122 strains of tomatoes were tried out at this station. This strain test is being used as the basis upon which to start some tomato breeding work. In this work the object is to improve our present early varieties of tomatoes and to secure a better quality and an earlier variety than any we have now. An individual plant record is kept of all the plants in the various strains, and the seed selected from the best plants. To gain a generation some plants are raised in the greenhouse over winter.

THE IDEAL TOMATO.

A good ideal to have in mind when selecting a variety of tomatoes for this section is,—to have a plant of the standard type of medium size with compact and vigorous growth, with the internodes of medium length; and with small and well distributed fruit clusters. The fruit should be of medium size, spherical shape, of a rich red color, having a smooth uncracked surface and a thin tough skin. The interior walls of the fruit should be thick and fine grained. The flesh should be thick and firm with very little or no hard core. The seed cavities should be small with very few seeds. (The sketches on Plate II will illustrate good and poor meat sections of tomatoes.) The calyx should be small and should part readily from the fruit. The plant should produce its fruit very early, about eight pounds before August 20th and in a season lasting till September 15th it should produce 25 pounds of marketable fruit per plant.

*CHARACTER OF
TOMATO INTERIORS*



Poor



Fair



Excellent



Good



Very Good

Plate II

TABLE VIII.—RESULTS OF STRAIN TEST OF EARLIANA.

Record Number	Name of Strain	Seedsman	Where Grown	Ave. Wt. of Marketable Fruit in oz.	Pct of Fruit Marketable	Yield in lbs. of Marketable Fruit Per Plant.			Color	Shape	Character of Interior
						To Aug 3	To Aug 20	Total			
1	Adirondack Earliana	Langdon	New York	3.5	86	1.14	9.65	27.8	R*	GFl†	VG††
2	Sparks Earliana	Bolgians	New York	3.8	78	1.21	7.78	22.3	R	GFl	G
3	Special Strain, Sparks Earliana	Burrell	Colorado	3.4	78	1.00	7.16	22.2	R	GFl	VG
4	Sparks Earliana (Langdon strain)	Dreer	Iowa	3.9	74	1.11	6.75	21.2	R	GFl	F
5	Sparks Earliana	Maule	Michigan	3.9	82	.42	4.71	18.	R	GFl	VG
6	Sunny Brook Special Earliana	Burpee	New Jersey	3.4	84	.48	5.23	22.	R	Gl	E
7	Sparks Earliana	Burpee	New Jersey	3.5	83	.62	4.56	16.6	R	GFl	G
8	Sparks Earliana	Northrup	Michigan	3.4	85	1.24	6.46	22.6	R	GFl	G
9	Earliana	Henderson	Long Island	3.6	84	1.43	6.49	22.8	R	GFl	G
10	Floracraft Earliana	Stokes	New Jersey	4.	78	.61	5.83	22.	R	Gl	VG
11	Sparks Earliana	Carter	New Jersey	3.6	84	.27	5.39	21.3	R	GFl	G

*R—Red; Pi—Pink; Pu—Purple; Y—Yellow. †Fl—Flat; GFl—Globular Flat; Gl—Globular; †† P—Poor; F—Fair; G—Good; VG—Very Good; E—Excellent.

In our trials some varieties have come up to this standard in the point of yield and some in the other features, but no one variety has come up to the standard in all features. In the variety and strain tests, twelve plants were raised of each strain, the records being kept of the ten middle plants of each plot. The plants were set 4.5 feet x 3.5 feet at the rate of 2760 plants per acre. The seed was sown March 26th and the plants transplanted twice, being finally grown in 3.5 inch clay pots and set in the field on May 20th.

EARLIANA.

At the present time the Earliana is the best general variety of tomatoes for this section. It is a light red, medium size, very early and a heavy yielding tomato. It is far from ideal, the fruit being generally quite rough and much cracked, of poor color, with many large seed cavities and the plants generally very susceptible to disease. Seed was secured from 10 different seedsmen, representing 11 different strains of this variety. This seed had been grown in six distinct sections of the country. From Table VIII it may be seen that very little variation occurred in size among the different strains, the greatest difference in the average weight per fruit being but .6 ounce. The percentage of marketable fruit is low in all cases. The most important variations are in yield (see Plate III and Table I and VIII). The average yield per plant to August 3rd, varies from .27 lb. to 1.43 lb.; to August 20th from 4.56 lb. to 9.65 lb. and the total yield to September 22nd varies from 16.6 lb. to 27.8 lb. The yield per acre can be estimated by multiplying the weight per plant by 2760 (the number of plants per acre) and using 50 lb. as the weight per bushel. The above total yields, in per acre terms, vary from 23 T to 38.5 T or 920 bushels to 1540 bushels per acre. The color and shape varied widely. The interior is seen to vary from fair to excellent (for explanation of terms see sketch on plate II.) It will be noticed that the more northern grown seeds produced the largest number of early tomatoes.

JUNE PINK.

Where a pink fruited variety is not objectionable, the June Pink is the best early variety. As will be seen from Table IX it is almost as early and yields almost as heavily as the Earliana. It is a globular, thick walled, thick meated tomato of good quality. The one serious objection to it is its thin skin which cracks very easily during wet weather.

MISCELLANEOUS EARLY VARIETIES.

Many seedsmen offer early tomatoes that they claim are earlier than any other variety and put them out under attractive names. In many cases these prove to be one of the standard early varieties,—generally the Earliana,—simply renamed and at other times they are an improvement of some old variety. This tendency to rename the standard varieties has a deplorable influence on the seed industry

TABLE IX.—RESULT OF STRAIN TEST OF JUNE PINK.

Record Number	Variety	Seedsman	Where Grown	Ave. Wt. of Fruit in oz.	Pct. of Fruit Marketable	Pounds of Marketable Fruit Per Plant.			Color	Shape	Character of Interior
						To Aug 3	To Aug 20	Total			
17.....	June Pink	Langdon	New York	4.0	79	.50	5.09	20.7	Pi	Gl	VG
18.....	June Pink	Stokes	New Jersey	4.4	87	.29	4.11	18.8	Pi	Gf	VG
19.....	June Pink	Dreer	New Jersey	4.0	79	.39	4.68	17.3	Pi	Gf	G
20.....	June Pink	Burpee	New Jersey	4.3	80	.64	5.19	20.8	Pi	Gf	G
21.....	June Pink	Northrup	Michigan	4.2	79	.81	5.98	19.7	Pi	Gf	VG

TABLE X.—RESULT OF VARIETY TEST OF MISCELLANEOUS EARLY VARIETIES.

33.....	John Baer	Bolgiano	New York	4.5	91	3.56	3.47	20.5	R	Gl	VG
34.....	Extra Early Wealthy	Bolgiano	New York	3.5	84	1.00	2.63	13.9	R	Gf	G
35.....	I X L	Bolgiano	New York	4.2	84	.41	2.87	13.4	R	Gf	VG
36.....	Prosperity	Bolgiano	New York	3.8	89	.15	2.72	18.6	R	Gf	E
39.....	Earliest of All	Maule	Connecticut	4.1	85	.05	2.33	20.9	R	Gf	E
45.....	Earibell	Northrup	Michigan	3.8	89	.17	2.16	19.3	R	Gf	E
86.....	Berry's Early Wonder	Berry	Michigan	3.9	86	.15	2.22	20.1	R	Gf	E
90.....	Rotkappchen	Salzer	California	2.7	80	.44	1.27	14.9	R	Gf	F
91.....	Earlist of All	Salzer	California	3.4	86	.17	2.24	16.0	R	Gf	F
101.....	Early Hustler	Livingston	Ohio	4.0	83	.11	1.25	17.8	R	Gf	E
112.....	Challenger	Damman	Italy	6.4	92	0	.56	13.4	R	Gf	VG
122.....	Alacrity	Can. Exp.Sta	Canada	4.6	87	.50	2.00	15.4	R	Gf	VE

and is becoming unpopular. In Table X are shown the results of the 1914 trials of some of these so-called new first early varieties. Some of them seem to be distinct sorts, while the others could not be distinguished from the Earliana. In this table no varieties were included that yielded less than a total of 13 lb. of marketable fruit per plant and because of this fact several other, so-called early varieties, were not included but are tabulated in the later tables. The writer wishes to call attention to the John Baer tomato (No. 33) listed in this table. It is a 1914 introduction that has been given considerable notoriety. The introducer claimed it to be the earliest tomato yet produced. In the station trials it was found to ripen the bulk of its crop at the same season as Chalk's Jewel and Bonny Best and later than Earliana and June Pink. The tomatoes were unusually uniform, globular, smooth and solid, with a very good interior. As a second early it is a very good variety. Another variety that promises to do well is the Alacrity (No. 122) which was secured from a Canadian Experiment Station.

BONNY BEST AND CHALK'S JEWEL.

The Bonny Best and Chalk's Jewel (Table XI) are two very similar varieties. They are large, bright red, generally globular fruited varieties. The Bonny Best generally has a few large symmetrical seed cells, with very thick walls and a thick rind. The Chalk's Jewel generally has many small, more unsymmetrically arranged cells. The Bonny Best is about one week earlier and its fruit is slightly smaller in size. The Bonny Best is being used by many seedsmen instead of Chalk's Jewel. These two varieties are very superior to the Earliana in quality, but cannot be substituted for it as a first early variety.

MEDIUM EARLY VARIETIES.

There are a number of medium early varieties that yield a fair crop in this region, and which have some especially desirable characteristics, such as very good quality, small or immense size or some other feature. On account of requiring a longer season, they do not produce a very large crop in North Dakota's short seasons. These varieties are roughly classified in Table XII. Most of them should not be grown in this section.

GLOBE.

The Globe is a purple variety, medium early, producing very smooth, globular, thick fleshed tomatoes a high percentage of which are marketable. It is a variety well worth trying where many tomatoes are grown, because of its excellent quality.

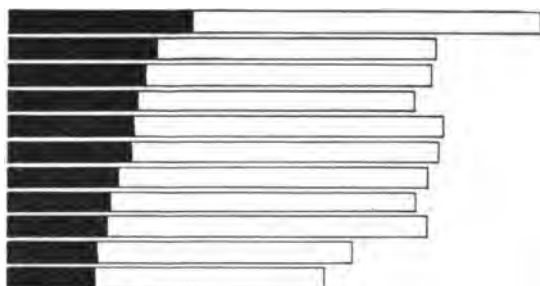
STONE.

The Stone (No. 63-65) is the standard late variety in the larger tomato growing sections of the country. It is a dark red, globular, flattened, thick meated tomato, producing very few inferior fruits. Until an early strain of this variety is developed, it should not be used very much in this state.

AVERAGE YIELD PER PLANT OF SEVERAL
STRAINS OF EARLY VARIETIES OF TOMATOES.
SEASON OF 1914.

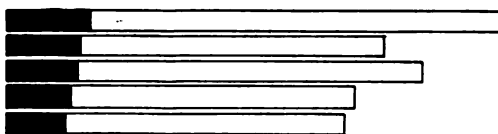
EARLIANA.

	Yield	
Proc. Co	Total	
No. Aug 24	Yield	
1	965	278
2	770	229
3	716	222
4	675	212
9	649	228
8	646	226
10	583	220
11	539	213
6	523	220
5	471	180
7	456	168



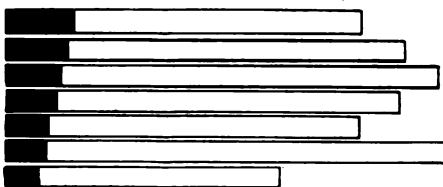
BONNY BEST.

16	440	259
14	397	195
15	377	217
13	343	182
12	318	177



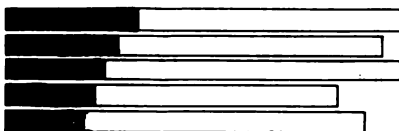
CHALK'S JEWEL.

23	366	186
22	327	208
26	288	226
25	273	206
27	221	185
28	214	230
24	170	143



JUNE PINK.

17	609	207
21	538	197
20	519	208
19	468	173
18	411	183



MIKADO.

The Mikado (No. 66-67) is a flat, purple red, thick meated tomato. The plant has the potato leaf type of foliage. It is an old standard variety, but is surpassed by many of our present day varieties.

ACME.

The Acme (No. 68) another of the older standard varieties, is a flat purplish pink, very thick meated tomato, but it is too late for our use.

GREATER BALTIMORE AND MY MARYLAND.

Greater Baltimore and My Maryland are two varieties that are very popular in more southern sections where they are standards for canning purposes. Both have many good qualities but lack earliness.

NOVELTIES—SMALL FRUIT, DWARF PLANTS, COLOR, SIZE.

For many purposes, small tomatoes used as whole tomatoes are desirable. In Table XIII is shown the record of a number of small fruited varieties. These varieties are very prolific and fairly early. They generally have two large cells, a small amount of meat, and a rather large amount of seed, which makes them rather undesirable for some purposes. The Sunrise, an English variety, and Victoria Whole Salad are very similar red varieties. The Comet is an old variety formerly used a great deal for forcing purposes. Early Minnesota is a pink fruited variety in this group.

For a small home garden the "Dwarf" or "Tree" tomatoes are very useful. Because of their small type they can be planted rather closely. The Dwarf Aristocrat and Dwarf Stone are red fruited and the Big Dwarf and Dwarf Champion are pink fruited varieties.

The Golden Ponderosa is like the regular Ponderosa except that it is of a yellow color and a milder flavor. Another yellow variety not listed in this trial is the Golden Queen.

If a tomato of greatest size is desired regardless of shape, there are several varieties that are early enough to be profitable that are very large. The record of two of these varieties is given in Table XII. The fruit of the Ponderosa (No. 6) a purplish red tomato averaged 6.7 ounces in weight and produced 8.9 lb. of tomatoes per plant. Landreth's Ever Large (No. 94) a dark red tomato produced 11.9 lb. of tomatoes per plant averaging 10.3 oz. per fruit. Both of these varieties produce very thick meated tomatoes with many small cells, but both varieties produce very rough tomatoes.

The Honor Bright (No. 80 and No. 100) is a distinct novelty. Its fruit changes from a green, to a white, then to a yellow, then to a light pink and finally to a light red color.

TABLE XI.—RESULT OF STRAIN TEST OF BONNY BEST AND CHALK'S JEWEL.

Record Number	Variety	Seedsman	Where Grown	Ave. Wt. of Marketable Fruit in oz.	Pct. of Fruit Marketable	Pounds of Marketable Fruit Per Plant.			Color	Shape	Character of Interior
						To Aug 3	To Aug 20	Total			
12.....	Bonny Best Early	Stokes	New Jersey	8.7	93	.17	3.18	17.7	R	Gl	VG
13.....	S. S. Bonny Best Early	Stokes	New Jersey	8.7	91	.07	3.43	18.2	R	Gl	VG
14.....	Bonny Best	Langdon	New York	4.8	89	.80	8.97	19.5	R	Gl	VG
15.....	Bonny Best	Dreer	Michigan	4.8	89	.42	8.77	21.7	R	Gl	VG
16.....	Bonny Best Early	Maule	Michigan	5.9	92	.42	4.40	25.9	R	Gl	VG
22.....	Jewel	Langdon	New York	4.8	94	.40	8.27	20.8	R	Gl	G
23.....	Chalk's Jewel	Stokes	New Jersey	4.1	93	.37	3.66	18.6	R	Gl	VG
24.....	Chalk's Early Jewel	Burrell	Colorado	4.4	95	.44	1.70	14.3	R	Gl	G
25.....	Chalk's Early Jewel	Maule	Michigan	4.1	94	.08	2.73	20.6	R	Gl	G
26.....	Chalk's Early Jewel	Henderson	Long Island	4.6	93	.22	2.88	22.6	R	Gl	VG
27.....	Chalk's Early Jewel	Burpee	Pennsylvania	5.4	90	.15	2.21	18.5	R	Gl	VG
28.....	Chalk's Early Jewel	Northrup	Michigan	8.7	95	.30	2.14	23.0	R	Gl	F

TABLE XII.—VARIETY TEST OF MIDSEASON TO LATE VARIETIES.

29.....	New Globe	Bolgiano	New York	5.2	92	.12	1.18	14.7	Pu	Gl	VG
30.....	Livingston's Globe	Stokes	New Jersey	4.5	93	0	.73	11.8	Pu	Gl	E
31.....	Livingston's Globe	Northrup	Michigan	4.7	89	.27	.85	12.7	Pu	Gl	VG
37.....	Cream City	Currie	Michigan	3.4	93	.12	1.33	12.3	Pi	Gl	VG
38.....	Imperial	Currie	Michigan	4.9	92	.13	1.10	9.8	Pi	Gl	VG
40.....	Sterling	Northrup	California	3.8	92	.04	.78	9.8	R	Gl	G
43.....	Fordhook Flat	Burpee	Pennsylvania	4.2	90	.07	1.16	10.5	Pu	Gl	VG
44.....	Early Detroit	Dreer	New Jersey	4.7	94	.24	.86	8.2	Pu	Gl	VG
47.....	Trucker's Favorite	Burpee	Pennsylvania	5.5	91	0	.52	7.5	Pi	Gl	VG
48.....	Trucker's Favorite	Maule	Connecticut	4.7	88	.02	.64	10.1	Pi	G	VG

49.....	Livingston's Beauty	Stokes	Michigan	4.1	93	94	1.28	9.3	Pu	GI	G
51.....	Early Freedom	Henderson	Long Island	2.8	96	16	.81	7.0	R	GI	G
61.....	Maule's Enormous	Maule	Connecticut	4.6	97	0	.34	7.3	R	GI	VG
62.....	Enormous	Olds	Michigan	5.2	92	0	.43	7.2	R	GI	G
63.....	Stone	Northrup	Delaware	4.2	97	.05	.59	10.2	R	GI	VG
64.....	Selected Stone	Dreer	Michigan	5.9	98	0	.08	7.6	R	GI	VG
65.....	Stone	Damman	Italy	5.4	91	0	.30	10.3	R	GI	VG
66.....	Mikado	Currie	Michigan	3.9	90	0	.85	12.7	PuR	F	VG
67.....	Mikado	Damman	Italy	5.3	97	0	.19	5.3	PuR	F	VG
68.....	Selected Acme	Maule	Michigan	4.8	95	.15	.74	12.9	Pu	F	VG
73.....	Maule's Success	Maule	New Jersey	4.7	98	0	.12	7.6	R	GI	VG
75.....	S. S. Main Crop	Stokes	New Jersey	6.1	78	0	.44	7.0	R	GI	VG
77.....	Greater Baltimore	Bolgiano	New York	4.8	87	.05	.84	8.7	R	GI	E
78.....	My Maryland	Bolgiano	New York	5.9	92	0	.53	11.1	R	GI	VG
81.....	Red Rock	Langdon	New York	5.3	88	.14	.66	7.3	R	GI	VG
95.....	Landreth's Red Rock	Landreth	Pennsylvania	5.8	95	0	.60	10.9	R	GI	VG
84.....	Livingston's Perfection	Livingston	Ohio	4.8	77	.03	.43	7.2	R	GI	VG
87.....	Ferris Wheel	Salzer	California	4.8	85	.11	.58	12.2	PuR	F	E
88.....	Five Million Dollar	Salzer	California	5.0	87	0	.55	9.0	R	F	VG
89.....	1900 or Crimson Whirl Wind	Salzer	California	5.1	93	.08	.91	11.6	R	GI	G
93.....	Ten Ton Tomato	Landreth	Pennsylvania	3.9	96	.06	.57	6.6	R	GI	G
96.....	Landreth's No Substitute	Landreth	Pennsylvania	3.1	97	0	.25	12.0	R	GI	VG
113.....	Express	Damman	Italy	2.6	98	.04	.85	9.7	R	GI	P
114.....	Monte Pellegrino	Damman	Italy	2.3	97	0	.09	7.6	R	GI	P
115.....	North Light	Damman	Italy	1.8	98	0	.52	6.5	R	GI	P
118.....	Italia	Damman	Italy	1.9	97	0	.51	8.8	R	GI	G

TABLE XIII.—VARIETY TEST OF SOME NOVELTIES IN TOMATOES

Record Number	Variety	Seedsman	Where Grown	Ave. Wt. of Fruit in oz.	Pct of Fruit Marketable	Pounds of Marketable Fruit Per Plant.			Color	Shape	Character Of Interior
						To Aug 3	To Aug 20	Total			
41.....	Sunrise	Carter	England	1.62	96	.13	1.38	16.6	R	Gl	P
42.....	Sunrise	Currie	England	1.69	95	.15	1.54	17.1	R	Gl	P
46.....	Early Minnesota	Northrup	Michigan	1.67	94	.24	1.28	12.4	Pi	Gl	F
86.....	Victoria Whole Salad	Burpee	New Jersey	1.7	95	.19	.75	16.3	R	Gl	G
97.....	Northern Latitude	Landreth	Pennsylvania	2.3	94	.23	.90	9.8	R	Gl	F
99.....	Comet	Carter	England	3.0	92	.22	.85	11.1	R	Gl	G
32.....	Dwarf Aristocrat	Livingston	Ohio	3.4	96	.06	3.40	8.1	R	GlFl	G
69.....	Big Dwarf	Currie	Michigan	5.5	91	0	1.22	7.0	Pu	GlFl	VG
70.....	New Dwarf Stone	Stokes	New Jersey	4.8	93	0	.56	4.4	R	GlFl	VG
71.....	New Dwarf Stone	Burpee	Pennsylvania	5.3	98	0	.64	4.9	R	GlFl	VG
72.....	Dwarf Champion	Dreer	New Jersey	3.1	92	0	.64	6.5	Pu	GlFl	G
82.....	Golden Ponderosa	Henderson	Long Island	6.5	92	0	.48	6.8	Y	Fl	VG
80.....	Honor Bright	Currie	Michigan	4.6	97	0	.12	5.0	R	GlFl	G
100.....	Honor Bright	Livingston	Ohio	3.1	99	0	.09	5.2	R	GlFl	G
76.....	Ponderosa	Henderson	Long Island	6.7	82	.09	.47	8.9	Pu	Fl	E
94.....	Landreth's Ever Large	Landreth	Pennsylvania	10.2	98	.04	.11	11.9	R	Fl	E

TABLE XIV. LATE VARIETIES UNSUITABLE FOR NORTH DAKOTA.

Record Number	Variety	Seedsman	Where Grown	Ave. Wt. of Marketable Fruit in g's.	Pounds of Marketable Fruit Per Plant.				Color	Shape	Character of Interior
					Total	Aug	To	To			
					20	Aug	Aug	Aug			
50	Livingston's Favorite	Livingston	Ohio	5.8	97	05	58	5.4	R	Gl Fl	VG
52	Hummer	Olds	Michigan	2.7	97	03	73	5.8	R	Gl	VG
53	New Coreless	Olds	Michigan	4.8	98	0	01	1.4	R	Gl Fl	E
54	Livingston's Coreless	Northrup	California	5.2	97	0	07	2.4	R	Gl Fl	E
55	Livingston's Royal Red	Livingston	Ohio	5.3	95	0	19	6.5	R	Gl Fl	VG
56	Henderson's Tenderloin	Henderson	Long Island	5.6	96	0	0	4.2	R	Gl Fl	VE
57	Crimson Cushion	Dreer	New Jersey	3.8	96	0	0	2.5	R	Fl	VG
58	Crimson Cushion	Henderson	Long Island	7.1	89	0	0	7	R	Fl	E
59	Matchless	Maule	Michigan	4.6	97	0	07	3.1	R	Fl	E
60	Matchless	Burpee	Pennsylvania	4.2	98	0	0	2.5	R	Fl	VG
74	Magnificent	Maule	New Jersey	5.4	87	0	5	4.4	R	Gl Fl	VG
79	Duke of York	Bolgiano	New York	7.8	84	0	0	2.3	Pu	Gl	E
92	Brimmer	Wood	Virginia	7.2	81	09	27	3.9	Pu	Gl Fl	E
98	Carter's Perfection	Carter	England	4.0	93	02	14	3.3	R	Gl Fl	VG
102	Princess	Livingston	Ohio	4.2	98	0	10	3.2	Pu	Gl Fl	VG
103	Magnus	Livingston	Ohio	4.2	100	03	03	2.3	Pu	Gl Fl	E
104	Paragon	Livingston	Phio	6.9	99	0	0	1.8	R	Gl Fl	VG
105	Atlantic Prize	Livingston	Ohio	3.8	90	04	12	5.8	R	Gl Fl	VG
107	Paradise Extra Early	Varela	Canary Islands	3.2	96	0	19	7.4	R	Gl Fl	VG
109	Prince of Naples	Damman	Italy	3.8	93	02	32	7.2	R	Fl	P
110	Ficarazzi	Damman	Italy	4.1	97	06	80	6.9	R	Fl	F
111	Wonder of San Giovanni	Damman	Italy	5.3	93	0	13	2.7	R	Gl	VG

VARIETIES VERY UNSUITABLE.

There are many varieties that will do well in some other localities, but do not do well here because they are either too late, or are too low yielders. A number of varieties coming in this class, that should not be grown in this state are listed in Table XIV. It will be seen that they produce very little early fruit and have a low total yield,—less than 5 lb. per plant.

SUMMARY ON VARIETIES.

From the records shown in the various tables it will be seen that there are comparatively few tomato varieties suitable for commercial purposes that do well in this state. There are a larger number of varieties suitable for home use. But there is a scarcity of really good early varieties. For home or commercial purposes it is best to use the Earliana for first early and the Bonny Best and Chalk's Jewel or perhaps John Bear for the main crop. Several of the varieties listed in Table IX could be used.

GOOD SEED AS A FACTOR IN TOMATO GROWING.

That there is as much variation within a variety as between varieties is shown by a comparison of the various strains listed in the several tables, especially Tables VIII and XI. In all these tables there is as great or greater, difference in earliness, total yield and size of fruit between the strains of one variety as between different varieties.

Take for instance the case of the Earliana (Table VIII and Plate III). The greatest yield prior to August 20th was 9.65 lbs. of tomatoes per plant as compared with the lowest yield of 4.71 lbs. The total yield for the season, among strains of the same variety varied from 16.6 lbs. to 27.8 lbs. of marketable tomatoes per plant. In per acre terms, the total yield varied from 23 tons or 920 bushels to 38.5 tons or 1540 bushels of marketable fruit per acre. As all the conditions were uniform for all strains, it is entirely reasonable to credit most of this variation to the quality of the seed. However, the best seed is not the cheapest. The price paid for Earliana tomato seed used in the trials, varied from 25 cents to \$5 per ounce. The results favored the higher priced seed.

EFFECT OF LOCATION WHERE SEED IS GROWN.

The 122 strains of tomato seed used were grown in 12 different states, in 3 European countries and in Canada. Twenty-six of the strains, which was the largest number grown in any one place, were grown in Michigan. In New Jersey were grown 19 strains; Northern New York 14; Ohio 11; Pennsylvania 10; Long Island 7; California 7; Connecticut 3; Colorado 2 and one strain each was grown in Delaware, Virginia and Iowa. Of those grown in foreign countries 4 were grown in England, 15 in Italy and one each in Spain and Canada.

From the various tables it will be noticed that the more northern grown seed is generally the better. However, it will also be noticed

that in many cases some of the more southern grown seed produced better results, showing that a northern location cannot be substituted for good breeding in tomatoes.

OPPORTUNITIES IN TOMATO RAISING.

There is quite an opportunity for developing a commercial tomato industry in this state. This opportunity lies in supplying our local markets with early tomatoes, growing tomatoes for canning factories,—more of which should be established in the state,—and canning tomatoes on the farm for home use and for sale.

YIELDS.

In a well cared for garden, on heavy North Dakota soils a yield of 20 lbs. per plant,—27 tons per acre or 1080 bushels per acre, is comparatively easy to produce, when proper methods are used. Under field conditions and with poorer soils, results three-fourths as good should be expected. More tomatoes should be raised for home use.

COST.

By using a pit manure hotbed a crop of tomato plants for one acre can be carried up to the ripening season for about \$100. That includes the original cost of the hotbed. After the first year the cost should not exceed \$15 or \$20 per acre. In addition to that it will cost almost 5 cents a bushel to pick the tomatoes.

TOMATOES FOR EARLY MARKET.

Farmers near good local markets can very profitably raise early tomatoes for their markets. The price of the earliest tomatoes varies from \$4 to \$1 per bushel and all through the season the price will seldom drop below 50 cents per bushel.

RAISING TOMATOES FOR CANNING FACTORIES.

Another opportunity is the raising of tomatoes for canning factories. The customary price paid for tomatoes by factories in this section is \$10.00 per ton. After paying for his own labor,—a grower should make a profit of \$50.00 to \$150.00 per acre, at that price. If a good market is close at hand for fresh tomatoes profits twice as great as this can be secured. At the present time, very few of the canned tomatoes used in this state are grown or canned in the state. A number of canning factories could profitably be run in various parts of the state in canning a general line of vegetables.

FARM CANNING.

All vegetables, especially tomatoes can profitably be canned for home use on the farm. Tomatoes can profitably be canned on the farm for market purposes. Farm canned goods are generally sold for a higher price than factory canned products. A number of portable farm canning outfits of varying size, style and cost are on the market at present. These portable canners are of three distinct kinds: (a) Hot water with open boiler; (b) hot water and steam combination;

and (c) steam pressure outfits. Outfits of this nature can be secured for from \$3.00 to \$15.00, that have a capacity of 200 or more No. 3 (2 lb.) cans of tomatoes per day. The No. 3 cans of tomatoes sell for about \$1.50 to \$1.80 a dozen retail or 15 cents a can. When charging for all fruit (at 25 cents a bushel) and for labor and cans, a No. 3 can of tomatoes can be put up for 5 cents and generally for less, thus netting the farmer 10 cents per can clear profit over buying canned tomatoes. When sold, the wholesale price varies from 90 cents to \$1.20 per dozen. A farmer's surplus can well be sold direct to consumers or through a local dealer. If a large quantity of tomatoes is to be canned a neat attractive label should be pasted on to every can. A select trade can be built up by canning all products in glass jars. There is considerable variation between the different varieties as to the number of cans of tomatoes that are produced from one bushel of fruit. There is generally more loss with the Earliana than with any other variety. About 16, No. 3 cans of tomatoes can be produced from a bushel of Earliana tomatoes. At this rate it will cost 80 cents to can one bushel of tomatoes. At \$1.00 per dozen these will be worth \$1.30, leaving a net profit of 50 cents a bushel for the fruit. As it is comparatively easy to raise 500 bushels of tomatoes per acre, it is very evident that the canning of tomatoes on a farm is quite profitable.

The following are brief instructions for canning tomatoes. Grade for ripeness, size and quality. Scald to loosen skins. Dip in cold water; remove skins; pack whole. Fill with tomatoes only and add one level teaspoonful of salt to each quart. Place rubber and partially seal. (Cap and tip tins.) Sterilize 22 minutes in hot water bath, 18 minutes in water seal outfit, 15 minutes under 5 pounds of steam or 10 minutes in pressure cooker. Remove jars, tighten covers, test joints and invert to cool. (For more complete instructions see Farmers Bulletin 521 or write to the Department of Agriculture, Washington, D. C., or to this station.)

SUMMARY.

Early tomatoes can best be grown by sowing the seed in a hot bed during the last part of March and transplanting twice, finally growing in tin cans, paper pots or earth pots in which they are held till set in the field about May 20th. Another way which is equally good is to sow the seed at the same time in dirt bands in which the plants are allowed to grow until transplanted to the field. Root pruning when done toward the end of the season increase the total yield. Seed sown in the field May 21st produced a profitable yield, but this method cannot be relied upon during most seasons.

The varieties best adapted to this section are the Earliana, Bonny Best, Chalk's Jewel, June Pink and a few other early varieties. A good average yield is 20 lbs. of usable tomatoes per plant. A yield of 25 lbs. and more per plant is frequently produced. A yield of 10 lbs. per plant will be quite profitable. One of the most profitable ways of disposing of a crop of tomatoes is by canning them on the farm.

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North Dakota
Agricultural Experiment Station

Fertility and Weeds

By J. W. Ince

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REPORT OF PROGRESS IN SUGAR BEET TRIALS

FOR THE SEASON OF 1914

During 1914 the Division of Agricultural Chemistry of the North Dakota Experiment Station continued the sugar beet trials which have been in progress for the past three* years in this state. The trials this season were carried on in co-operation with the Agronomy Division of the Experiment Station, the five Sub-stations, and eighty-seven farmers scattered over the state. From these co-operators there were submitted a total of one hundred and six (106) samples, ninety-four (94) from the Experiment Station and the Sub-stations and twelve (12) from farmers. The results of the analyses of these samples and information regarding the cultural treatment and the climatic conditions under which the beets were grown are given in the present report.

The samples generally seemed to be of satisfactory quality and condition, comparing most favorably in these respects with those grown in previous years. Some of the beets, however, had started second growth, which lowered the supply of sugar already in the beet. Another factor which might possibly have tended to lower the percentage of sugar was the superabundance of ground space allowed the beets while growing. Reference to Table V shows that the rows were usually from 30 to 36 inches apart and the beets 8 to 10 inches apart in the row. In sugar beet districts the usual conditions allowed are rows about 24 inches apart and beets about 8 inches apart in the row. The conditions of growth for the beets described in the present report would allow them to attain a larger size than that desired.

The year's work developed into a more critical study of eight varieties at the Experiment Station and on the Sub-stations at Edgeley and Williston. All of these varieties had been grown in the previous year so that an opportunity was thus afforded to study their record for two years. Those varieties which seem to exhibit a superiority in regard to the amount of sugar in the beet are as follows: Nos. 1, 2, 3, 4, 5, 7, 11. For the year 1913 these seven varieties had the following standing in the order of highest percentage sugar, 5, 11, 3 and 4 (tied), 2, 7, 1. For the year 1914 the order was 3, 4, 7, 1, 2, 5, 11. Assigning arbitrary values to these positions it will readily be seen that, as an average of the two years, the varieties that have the best record are 3, 4, and 5, in the order stated. Upon reference to Table VII, these are found to be Klein Wanzleben Original, and the strains of the Wohanka variety. The variety used at Billings, Montana, comes next to these three in order of standing.

Another phase of sugar beet trials was also undertaken, namely the effect of the length of the growing season upon the sugar content of the beets. At each station one variety was planted twice, the second date following two weeks after the first, and all the varieties

*Trials have been carried on for 12 separate years at indefinite periods beginning in 1899. In 1911 experimental work was started anew and continued intensively until 1914.

were harvested three times with an interval of two weeks between the harvesting dates. The samples from all the stations increased steadily in sugar content from the first to the third harvesting, with the single exception of the third series from the Experiment Station. These samples were quite inferior to the others from this locality for a number of reasons. Late rains had induced second growth, the beets were larger than those of the other two series, and they had apparently not been chosen as carefully in the field. It is interesting to note that the second planting of one variety at the Williston Sub-station gave beets of better quality than the first planting for all three of the harvestings. The detailed results of these two features are indicated later in the tables of analyses.

The samples from the Sub-station at Williston were of excellent quality, increasing from an average of nearly 18 per cent to 20 per cent sugar in the month of extra growth. This is all the more important since the average weight or size of the beets in the samples also increased. Usually, with other conditions equal, the larger the beet the lower the percentage of sugar. This year's trials at the Williston Sub-station confirm the results of previous years, namely that the soil and climatic conditions there are admirably suited for sugar beet production.

In view of the fact that the year's work was principally upon the samples from the Experiment Station and the Sub-stations at Edgeley and Williston, a further study was made of all the samples and trials reported for these stations in the past five years. Tables showing these comparisons have been compiled and appear later in the report.

For commercial purposes a beet of over 12 per cent sugar content corresponding to 12.5 to 13.5 per cent sugar in the juice, at least 80 per cent purity, and which weighs between one and four pounds, is considered the most desirable. The contracts of most sugar companies with the farmers are based on these figures, but at times variations from them are accepted. With these facts in mind one may form an opinion of the manufacturing value of the beets reported in the tabulated data.

The following tables give the results of the analyses of the samples for the season 1914; Table No. I for the Experiment Station, Table No. II for the Edgeley Sub-station, Table No. III for the Williston Sub-station, and Table No. IV for the miscellaneous samples from other co-operators. Table No. V contains information in regard to the cultural treatment of the beets. Table No. VI gives a summary of the results by varieties for 1914. Table No. VII gives information in regard to the varieties used in the 1914 trials. Table No. VIII contains the meteorological data for the Experiment Station and the Sub-stations at Edgeley and Williston for 1914.

The following tables give the summaries of the trials for these three stations for a period of years; Table No. IX the meteorological data and Table No. X the analytical data of all samples grown. Table No. XI is a comparison of the analyses of the varieties used in the 1913 and 1914 trials. Table No. XII contains a summary of all sugar beet analyses reported for North Dakota.

Figure 1 illustrates the curves of the mean daily temperature at the Experiment Station during the months of the growing season for the years 1910-1914. Figure 2 illustrates the same feature for the Williston Sub-station. Figure 3 shows diagrammatically the distribution of the rainfall and sunshine by months for the years 1911-1914 at the Experiment Station. Figure 4 shows the relation of the analytical data of the samples grown at the Experiment Station for the years 1911-1914. Figure 5 shows the relation of the analytical data of the samples from the Sub-station at Williston for the three dates of harvesting in 1914.

ACKNOWLEDGEMENT.

The writer desires to acknowledge the assistance of the following in furnishing samples for these trials: The Agronomy Division of the Experiment Station, the Superintendents of the Sub-stations at Williston and Edgeley, and the other co-operators. Also the agents who supplied the seed, and Mr. O. A. Stevens, who made the germination tests.

TABLE NO. 1.
ANALYTICAL DATA OF SAMPLES GROWN AT THE EXPERIMENT STATION,
1914.

Lab. No.	Variety	Per Cent Sugar in Beet	Per Cent Sugar in Juice	Degree Brix†	Per Cent Purity	Average Weight of Beets (Grams)	Date Harvested
1	1	15.20	15.96	18.2	88	510	September 28th
2	2	14.60	15.33	18.2	84	430	" "
3	3	14.70	15.44	19.3	80	440	" "
4	4	15.10	15.85	18.2	87	393	" "
5	5	14.50	15.23	18.2	84	430	" "
6	6	13.80	14.50	18.2	80	548	" "
7	7	13.70	14.38	18.2	79	483	" "
8	8	12.90	13.55	15.9	85	537	" "
9	9	12.90	13.55	17.0	80	539	" "
10	10	14.00	14.70	18.2	81	477	" "
11	11	14.60	15.33	17.0	90	460	" "
12	12	14.80	15.54	17.0	91	470	" "
13	7*	13.50	14.27	15.9	90	547	" "
14	14	14.10	14.81	15.9	93	477	" "
Average, 1st Harvest..		14.17	14.88	17.5	85	481	
41	1	15.10	15.85	18.2	87	502	October 12th
42	2	15.10	15.85	18.2	87	326	" "
43	3	16.00	16.80	20.4	87	478	" "
44	4	15.40	16.17	19.3	84	493	" "
45	5	15.41	16.17	19.3	84	531	" "
46	6	15.30	16.07	19.3	83	550	" "
47	7	15.90	16.70	20.4	82	545	" "
48	8	15.10	15.85	18.2	87	590	" "
49	9	15.20	15.96	18.2	88	404	" "
50	10	15.00	15.75	18.2	87	465	" "
51	11	15.60	16.37	18.2	90	482	" "
52	12	14.90	15.65	18.2	86	540	" "
53	7*	14.00	14.70	18.2	81	586	" "
53	14	15.00	15.75	18.2	87	558	" "
Average, 2nd Harvest..		15.21	15.97	18.7	86	504	
71	1	17.20	18.06	20.4	89	590	October 26th
72	2	16.60	17.42	18.2	96	460	" "
73	3	15.60	16.38	19.3	85	615	" "
74	4	14.50	15.23	19.3	79	645	" "
75	5	15.20	15.96	19.3	83	505	" "
76	6	14.40	15.13	18.2	83	470	" "
77	7	15.00	15.75	18.2	87	538	" "
78	8	14.40	15.13	18.2	83	720	" "
79	9	13.90	14.60	18.2	80	537	" "
80	10	13.80	14.50	18.2	80	580	" "
81	11	15.00	15.75	19.3	82	570	" "
82	12	14.30	15.00	18.2	83	625	" "
70	7*	13.20	13.85	18.2	76	695	" "
83	14	14.50	15.23	19.3	79	470	" "
Average, 3rd Harvest..		14.83	15.57	18.7	83	573	

SUMMARY.

1st Harvest	Min.	12.9	13.55	15.9	79	393	
" "	Max.	15.2	15.96	19.3	93	548	
" "	Mean	14.2	14.88	17.5	85	481	
2nd Harvest	Min.	14.0	14.70	18.2	81	326	
" "	Max.	16.0	16.80	20.4	90	590	
" "	Mean	15.2	15.97	18.7	86	504	
3rd Harvest	Min.	13.2	13.85	18.2	76	460	
" "	Max.	17.2	18.06	20.4	96	720	
" "	Mean	14.8	15.57	18.7	83	573	
All	Min.	12.9	13.55	15.9	76	326	
" "	Max.	17.2	18.06	20.4	96	720	
" "	Mean	14.2	15.48	18.3	85	509	

NOTE.—*Second Planting. †The degree Brix is the percentage by weight of sucrose in a pure sugar solution.

TABLE NO. II.
ANALYTICAL DATA OF SAMPLES GROWN AT EDGELEY SUB-STATION, 1914.

Lab. No.	Variety	Per Cent Sugar in Beet	Per Cent Sugar in Juice	Degree Brix	Per Cent Purity	Average Weight of Beets (Grams)	Date Harvested
37	1	14.60	15.33	18.2	84	950	October 7th
36	1	14.90	15.64	20.4	77	855	" "
38	1	14.70	15.43	18.2	85	920	" "
21	2	15.40	16.17	20.4	79	768	" "
22	2	16.00	16.80	20.4	82	740	" "
23	2	15.70	16.48	20.0	82	760	" "
34	5	16.20	17.00	20.4	83	705	" "
35	5	15.60	16.38	19.3	85	730	" "
33	5	16.00	16.80	20.4	82	730	" "
24	6	16.00	16.80	19.3	87	810	" "
25	6	14.50	15.23	18.9	81	830	" "
26	6	15.80	16.58	19.3	86	760	" "
30	8	14.10	14.80	18.2	81	830	" "
31	8	13.00	13.66	18.2	75	840	" "
32	8	14.10	14.80	18.2	81	860	" "
27	8	15.80	16.58	18.2	91	820	" "
28	8	14.10	14.80	18.2	81	780	" "
29	8	14.00	14.70	19.3	76	815	" "
Av.	1*	14.73	15.43	18.9	82	908	" "
"	2*	15.70	16.46	20.3	81	756	" "
"	5*	15.93	16.73	20.0	83	722	" "
"	6*	15.43	16.20	19.2	85	760	" "
"	8*	14.18	14.89	18.4	81	824	" "
Average, 1st Harvest...		15.03	15.77	19.2	82	806	
68	1	16.30	17.11	20.4	84	817	October 19th
69	2	16.80	17.63	21.5	82	730	" "
66	5	15.80	16.58	19.3	86	686	" "
67	6	16.10	16.90	21.5	79	734	" "
64	8	13.50	14.17	19.3	74	930	" "
65	8	13.80	14.50	18.2	80	660	" "
Av.	8†	13.65	14.33	18.8	77	795	" "
Average, 2nd Harvest...		15.40	16.15	20.0	81	760	
95	1	16.10	16.90	20.4	83	825	October 31st
96	2	17.80	18.70	22.6	83	710	" "
97	5	18.40	19.33	22.6	86	840	" "
98	6	16.60	17.43	21.5	81	825	" "
99	8	15.20	15.96	19.8	81	830	" "
100	8	14.90	15.65	19.3	81	755	" "
Av.	8†	15.05	15.80	19.6	81	792	" "
Average, 3rd Harvest...		16.50	17.33	21.0	83	798	

SUMMARY.

Harvest	Averages	Per Cent Sugar in Beet	Per Cent Sugar in Juice	Degree Brix	Per Cent Purity	Average Weight of Beets (Grams)
1st	Min.	13.00	13.66	18.2	75	705
	Max.	16.20	17.00	20.4	91	950
	Mean	15.03	15.77	19.2	82	806
2nd	Min.	13.50	14.17	19.3	74	660
	Max.	16.80	17.63	21.5	86	930
	Mean	15.40	16.15	20.0	81	760
3rd	Min.	14.90	15.65	19.3	81	710
	Max.	18.40	19.33	22.6	86	840
	Mean	16.50	17.33	21.0	83	798
All	Min.	13.00	13.66	18.2	74	660
	Max.	18.40	19.33	22.6	91	950
	Mean	15.40	16.16	20.4	82	800

*These are averages of the samples which are given separately above, of the corresponding variety.

†Two (2) sub-samples of variety No. 8 were forwarded at the second and third harvest from this Sub-station.

TABLE NO. III.
ANALYTICAL DATA OF SAMPLES GROWN AT WILLISTON SUB-STATION, 1914.

Lab. No.	Variety	Per Cent Sugar in Beet	Per Cent Sugar in Juice	Degree Brix	Per Cent Purity	Average Weight of Beets (Grams)	Date Harvested
20	1	17.00	17.76	19.3	92	576	September 28th
17	3	17.20	18.06	21.1	86	415	" "
18	3 (a)	19.10	20.07	21.5	93	561	" "
15	4	19.60	20.58	23.7	87	520	" "
16	7	18.10	19.00	21.5	88	520	" "
19	8	16.70	17.55	20.4	86	555	" "
Average, 1st Harvest...		17.95	18.84	21.25	88.7	524	" "
61	1	19.60	20.58	22.6	91	507	October 12th
58	3	19.30	20.26	23.7	86	565	" "
59	3 (a)	20.80	21.83	24.8	88	485	" "
62	4 (b)	20.70	21.72	25.9	84	512	" "
63	4 (c)	19.30	20.27	24.8	82	870	" "
56	7 (b)	18.70	19.64	21.5	91	582	" "
57	7 (c)	18.60	19.53	23.7	83	1135	" "
60	8	17.60	18.48	21.5	86	625	" "
Av.	4 (d)	20.00	20.99	25.3	83	691	" "
"	7 (d)	18.65	19.58	22.6	87	858	" "
Average, 2nd Harvest...		19.32	20.30	23.56	86.4	660	" "
92	1	19.30	20.27	22.6	90	493	October 26th
88	3	20.00	21.00	24.8	85	480	" "
90	3 (a)	20.70	21.73	23.7	92	450	" "
86	4 (b)	21.00	22.05	27.0	82	626	" "
91	4 (c)	19.50	20.47	23.7	86	795	" "
87	7 (b)	20.20	21.20	23.7	90	740	" "
85	7 (c)	19.40	20.38	23.7	86	1366	" "
89	8	20.10	21.10	23.7	89	498	" "
Av.	4 (d)	20.25	21.26	25.3	84	710	" "
"	7 (d)	19.80	20.79	23.7	88	1053	" "
Average, 3rd Harvest...		20.03	21.03	24.11	87.5	681	" "

SUMMARY.

Harvest	Averages	Per Cent Sugar in Beet	Per Cent Sugar in Juice	Degree Brix	Per Cent Purity	Average Weight of Beets (Grams)
1st	Min.	16.70	17.55	19.3	86.0	415
	Max.	19.60	20.58	23.7	93.0	576
	Mean	17.95	18.84	21.2	88.7	524
2nd	Min.	17.60	18.48	21.5	82.0	485
	Max.	20.80	21.83	25.9	91.0	1135
	Mean	19.32	20.30	23.6	86.4	660
3rd	Min.	19.30	20.27	22.6	82.0	450
	Max.	21.00	22.05	27.0	92.0	1366
	Mean	20.03	21.03	24.1	87.5	681
All	Min.	16.70	17.55	19.3	82.0	415
	Max.	21.00	22.05	27.0	93.0	1366
	Mean	19.20	20.10	23.1	87.4	630

- (a) Second planting.
 (b) Sample of beets smaller than the average size.
 (c) Sample of average size beet.
 (d) Average of the two sub-samples of this variety.

NOTES IN REGARD TO SAMPLES.

From the Experiment Station: First series, tops green, prongy, many large roots, second growth. Second series, same condition as first series. Third series, second growth, hard and watery, topped heavily, very inferior samples. The heavy rains of the early part of the season so packed the ground that the roots could not penetrate very deep, causing deformed shapes, forked roots, etc. The beets made their greatest growth in August and the first part of September.

From the Sub-station at Edgeley: First series, good condition, although some second growth. Second series, too large beets. Third series, good condition but some second growth. The early part of the season was favorable, but it was dry later. Owing to a misunderstanding, the harvesting dates were changed from those used at the other Stations.

From the Sub-station at Williston: First series, most beets weighed two pounds or over, but those selected were between one and two pounds. The tops were still green and upright, and scarcely wilted. Condition when received good. Second series, tops still green and mostly upright, a few leaves at the crown beginning to dry up. Because the size of the beets in the samples called for was smaller than the size of the average beet in the field, extra samples of the latter of varieties Nos. 4 and 7 were also shipped. Samples delayed in shipment and when received were not in as good condition as the first series, having lost some moisture. The roots had been cut too short also. Third series, somewhat dried out when received, and some had apparently been slightly frozen in the tap root, probably in transit, otherwise good condition.

Total weight of all beets on one-tenth acre, taking into account weights of all samples previously taken, was 3,357 pounds, or at the rate of 16.79 tons per acre for all samples. Average weight of beets on plat 2.25 pounds. Record No. 3, planted two weeks later than the others averaged 1.5 pounds per beet, and Billings and Terra averaged 2.75 to 3 pounds, while Wohanka Z. R. averaged 3 to 3.25 pounds per beet.

Yields of beets were as follows for each variety: No. 1, Klein Wanzleben, Old Type, 17.6 tons; No. 3, Klein Wanzleben, Original, 19.57 tons;—same planted two weeks later, 14.28 tons; No. 4, Wohanka Z. R. 15.92 tons; No. 7, B. & L.—Productive No. 2 (Billings), 17.68 tons; No. 8, Terra, 11.08 tons. The low yields were due to poor stand more than to anything else.

The beets were irrigated on July 27 and August 18.

TABLE NO. IV.
ANALYTICAL DATA OF MISCELLANEOUS SAMPLES, 1914.

Lab. No.	Cooperator	Town	County	Variety	Sugar in Beet	Sugar in Juice	Degree Brix	Per Cent Purity	Average Weight Beets
39	Sargent Bros.	Towner	McHenry	2	15.00	15.75	18.2	87	520
54	Normal School	Mayville	Trall	2	14.60	15.32	17.0	90	642
55	Roller Mill	Walhalla	Pembina	2	11.70	12.28	15.9	77	1542
84	Rudolph Slaby	Beach	Golden Valley	8	18.90	19.85	23.7	84	543
93	Emmel Hoffman	Walum	Griggs	2	15.80	16.58	19.3	86	780
94	J. R. Nokman	Spring Brook	Williams	2	18.10	19.02	23.7	80	541
101	F. J. Pankow	Hankinson	Richland	6	12.80	13.44	17.1	79	1158
103	T. Sanderson	Fargo	Cass	3	14.00	14.70	19.3	76	792
102	R. Ruff	Silva	Pierce	4	15.30	16.16	20.4	79	437
104	Demonstration Farm	McLeod	Ransom	2	18.10	19.02	23.7	80	497
105	G. W. Dyson	Cooperstown	Griggs	8	15.00	15.75	20.4	77	587
106	R. C. Hudson	Balfour	McHenry	7	16.60	17.42	22.6	77	953
Average of 12 samples					15.50	16.29	20.1	81	749

TABLE NO. V.
CULTURAL TREATMENT OF BEETS.

Cooperator	Date of Plowing	Depth of Plowing	Date of Planting	Date of Thinning	Dates of Cultivation	Date of Harvest	Distance Between Rows	Distance Apart in Rows
Agronomy Division, Experiment Station.....	Fall.....	7"	May 28 to June 1.....	June 22-24.....	June 24, July 8 and 18.....	Sept. 28 Oct. 12 and 26.....	36"	7"
Sub-station, Edgeley, O. A. Thompson, Supt.....	May.....	6"	May 25.....	June 10.....	June 1, 10, 25, July 1, 15.....	Oct. 8, 19 and 31.....	36"	36"
Sub-station, Williston, C. H. Kuzicka, Supt.....	May 21.....	8-9"	May 21.....	June 30.....	June 10, 24, 30, July 14 and 21.....	Sept. 28 Oct. 12 and 26.....	24"	10"
Mayville Normal School, C. E. Tharaldsen.....	Fall.....	10"	May 16.....	June 12.....	June 5.....	Oct. 23.....	30"	8-10"
Rudolph Slaby.....	Fall.....	12"	May 24.....	July 7.....	July 2.....	Oct. 23.....	36"	6"
Emmel Hoffman.....	Spring.....	8"	May 24.....	July 6.....	June 30.....	Oct. 29.....	36"	6"
J. R. Notman.....	April.....	7"	May 24.....	July 6.....	July 16.....	Oct. 31 Nov. 3.....	32"	8"
F. J. Pankow.....	May.....	6"	May 12.....	July 2.....	.....	Oct. 31.....	24"	8"
G. W. Dyson.....	Fall.....	8"	May 10.....	.....	.....	.....	.....	.....
I. Sandersou.....	Spring.....	.....	April 30.....	.....	.....	.....	.....	.....

TABLE NO. VI.
AVERAGE OF ANALYSES BY VARIETIES, 1914.
SAMPLES FROM THE EXPERIMENT STATION AND THE EDGELEY AND
WILLISTON SUB-STATIONS.

Variety Number	Number Samples	Per Cent Sugar in Beet	Per Cent Purity	Average Weight (Grams)
1	11	16.36	86	686
2	8	16.00	84	615
3	9	18.15	87	499
4	8	18.13	84	607
5	8	15.90	84	645
6	8	15.31	85	691
7	11	16.40	85	703
8	16	14.95	82	788
9	3	14.23	83	493
10	3	14.27	83	507
11	3	15.07	87	504
12	3	14.66	87	545
14	3	14.53	86	502
Total.....	94	16.00	84.4	633

TABLE NO. VII.
VARIETIES OF SUGAR BEET SEED USED IN 1914 EXPERIMENTS.

No.	Name of Variety	Name and Address of Grower	Name and Address of Agent	Sprouts from 50 Balls
1	Klein Wanzleben, Old Type	Sugar Factory, Klein Wanzleben, Germany.....	Alex Fick, Omaha, Nebr.....	61
2	Klein Wanzleben, Pioneer..	Sugar Factory, Klein Wanzleben, Germany.....	Alex Fick, Omaha, Nebr.....	65
3	Klein Wanzleben, Original..	Sugar Factory, Klein Wanzleben, Germany.....	Alex Fick, Omaha, Nebr.....	56
4	Wohanka, Z. R.....	Wohanka & Co., Prague, Bohemia, Austria.....	C. W. deRekowski, Detroit, Mich.....	69
5	Wohanka, E. R.....	Wohanka & Co., Prague, Bohemia, Austria.....	C. W. deRekowski, Detroit, Mich.....	71
6	Schreiber.....	G. Schreiber & Son, Nordhausen, Germany.....	Allen G. Freeman, San Francisco, Cal.....	56
7	Productive No. 2.....	K. Buszczynski and M. Lazynski, Niemiercze, Russia..	Billings Sugar Co., Billings, Mont.....	71
8	Terra.....	Terra Aktiengesellschaft fur Samenzucht of Ascherleben, Germany.....	J. S. Jenks, San Francisco, Cal.....	50
9	Mette's Elite.....	Henry Mette, Quedlinburg, Germany.....	Edmund Starke, Detroit, Mich.....	46
10	Schobbert's Specialty.....	Carl Schobbert & Co.....	Meinrath Brokerage Co., Chicago.....	67
11	Schobbert's Ideal.....	Carl Schobbert & Co.....	Meinrath Brokerage Co., Chicago.....	53
12	Dippe.....		Great Western Sugar Co., Longmount, Colo.....	66
14	Royal Dutch.....	Messrs. Kuhn & Co., Naarden, Holland.....	M. van Waveren & Co., New York, N. Y.....	57

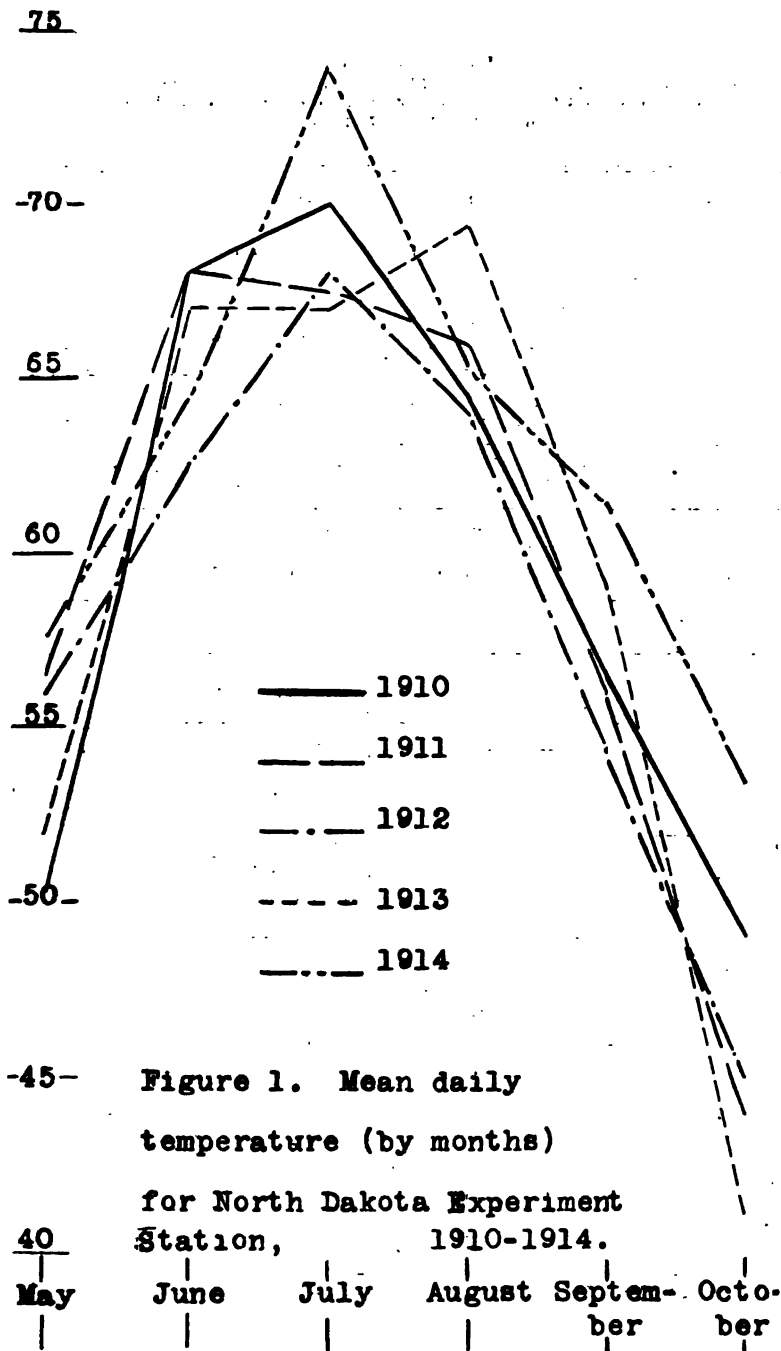


TABLE NO. VIII.
METEOROLOGICAL DATA FOR NORTH DAKOTA EXPERIMENT STATION
AND THE EDGELEY AND WILLISTON SUB-STATIONS.
MAY TO OCTOBER, 1914.
EXPERIMENT STATION

Month	Temperature			Rainfall	Sunshine, Hours		First Frost
	Max.	Min.	Mean	Inches	Total	Mean Daily	
May.....	68	47	57.5	0.81	238.5	7.9	
June.....	74	55	64.5	6.28	195.6	6.5	
July.....	85	63	74.0	3.10	299.6	9.7	
Total.....			65.3	10.10	733.7	8.0	
August.....	77	54	65.5	2.11	171.5	5.5	
September.....	73	50	61.5	0.80	140.8	4.7	
October.....	64	43	53.5	1.01	206.0	6.6	October 14, 29° October 26, 23°
Total.....			60.2	3.92	518.3	5.6	
Sum Total.....			62.1	14.11	1252.0	6.8	

WILLISTON SUB-STATION

Month	Temperature			Rainfall	Sunshine	First Frost
	Max.	Min.	Mean	Inches	%	
May.....	67	42	55.0	1.19	63	
June.....	73	51	62.0	6.58	55	
July.....	87	60	73.0	2.32	83	
Total.....			63.3	10.19	67	
August.....	77	50	64.0	3.22	68	
September.....	72	45	59.0	0.46	74	
October.....	61	36	49.0	0.38	59	October 24—29° October 25—27° October 26—17°
Total.....			57.3	4.06	67	
Sum Total.....			60.3	14.25	67	

EDGELEY SUB-STATION

Month	Temperature			Rainfall	Sunshine	First Frost
	Max.	Min.	Mean	Inches	%	
May.....	71	43	57.0	1.58	x	
June.....	75	52	63.0	4.04	x	
July.....	87	57	72.0	2.60	x	
Total.....			62.2	8.22	x	
August.....	78	51	64.5	1.90	x	
September.....	76	45	60.5	1.90	x	
October.....	66	37	51.5	0.96	x	
Total.....			58.8	4.76		
Sum Total.....			61.5	12.98		

NOTE.—Temperatures are average of maximum, minimum and mean. x Not secured.

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.....1909

————1910

—— ———1911

— . . . —1912

-----1913

-----1914

4540

May

June

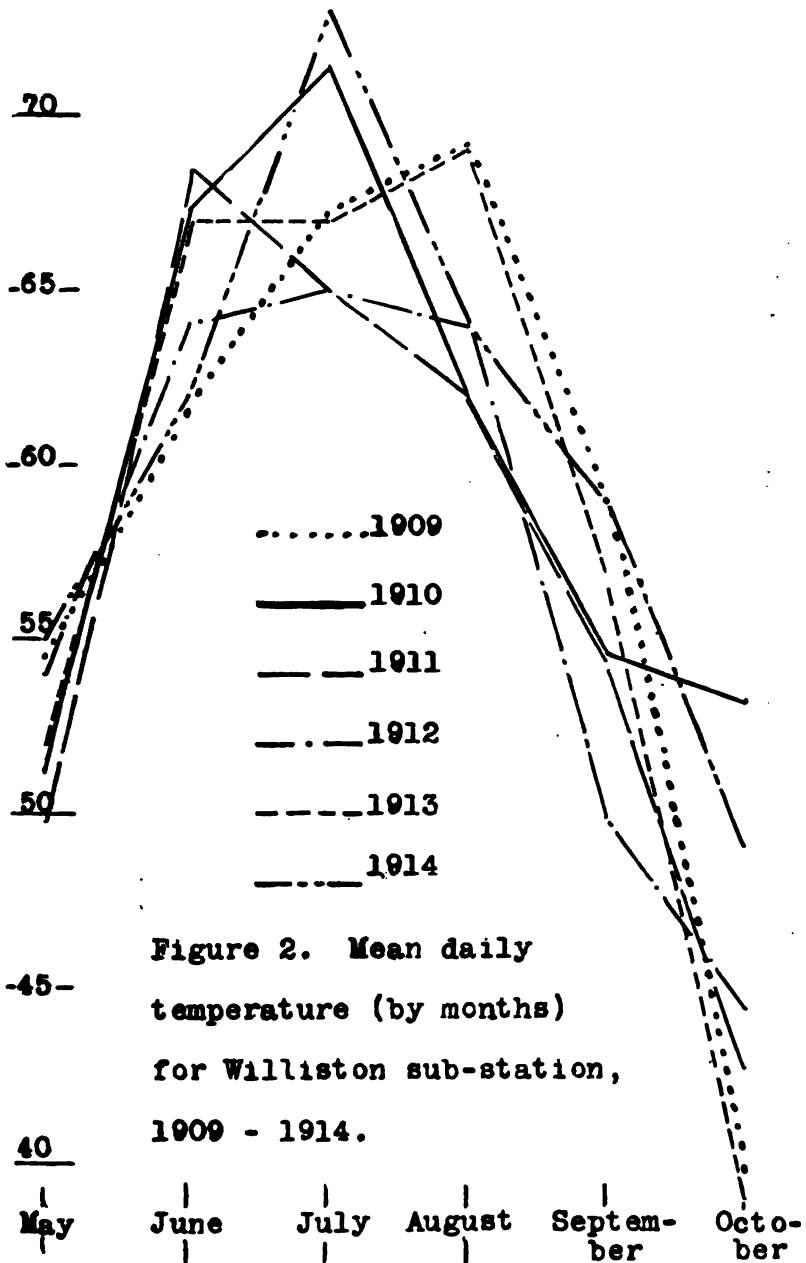
July

August

September

October

Figure 2. Mean daily
temperature (by months)
for Williston sub-station,
1909 - 1914.



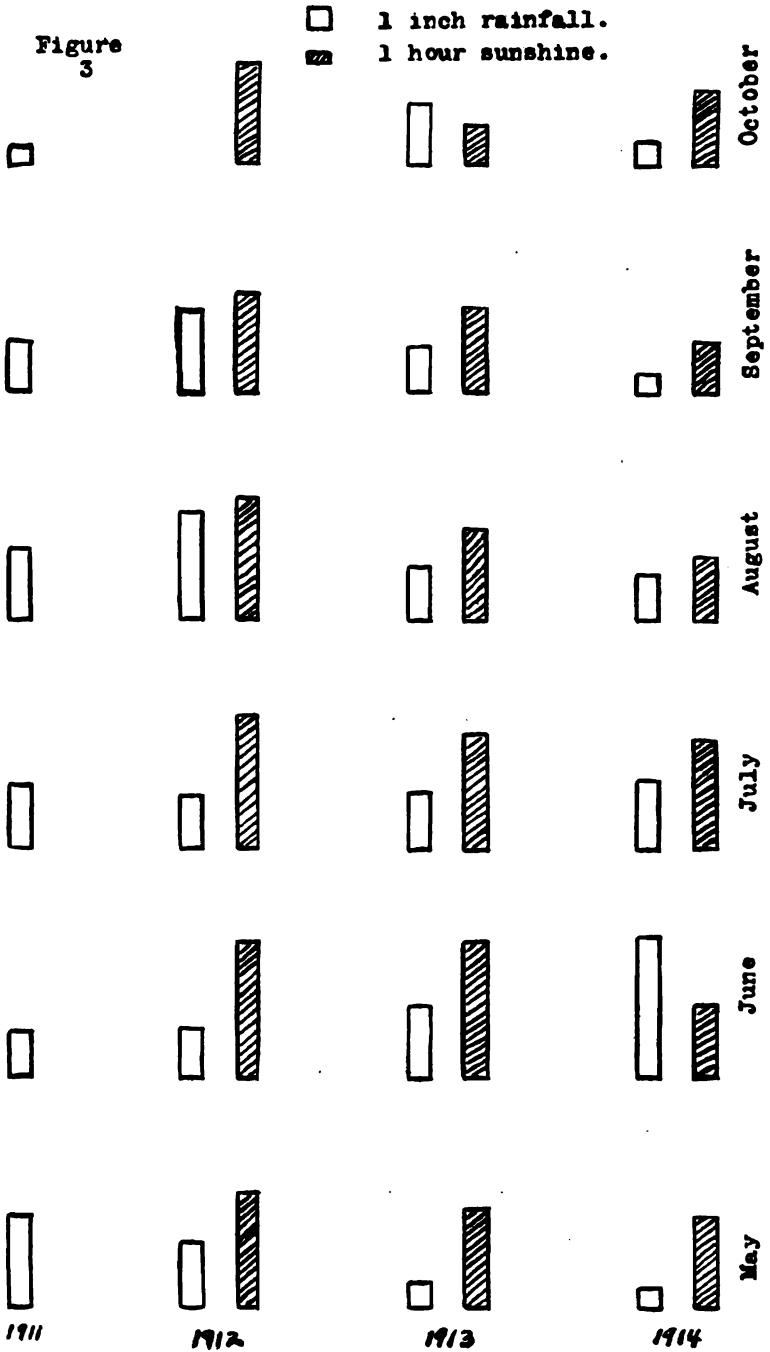


Fig. 3—Rainfall (inches) per month, and sunshine (average hours per day) at the North Dakota Experiment Station, 1911-1914.

TABLE NO. IX.
SUMMARY OF METEOROLOGICAL DATA, MAY-OCTOBER.

Year	Mean Daily Temperature	Rainfall (inches)	Sunshine (hours)
OBSERVATIONS AT EXPERIMENT STATION			
1911	59.5	14.98	No record
1912	58.4	16.01	1850
1913	59.2	13.90	1537
1914	62.1	14.11	1252
OBSERVATIONS AT WILLISTON SUB-STATION			
1909	58.5	8.10	No record
1910	59.3	7.45	" "
1911	57.5	8.61 (Apr.-Aug.)	" "
1912	57.0	16.59	" "
1913	60.0	12.58	" "
1914	60.3	14.25	" "
OBSERVATIONS AT EDGELEY SUB-STATION			
1911	59.0	12.60	No record
1912	59.0	18.17	" "
1914	61.5	12.98	" "

TABLE NO. X.
SUMMARY OF ANALYTICAL DATA.

Year	Number Samples Represented	Mean Weight Topped Beets (Grams)	Estimated Yield Per Acre (Tons)	Average Per Cent Sugar in Beet	Average Per Cent Purity Coefficient of Juice
SAMPLES GROWN AT EXPERIMENT STATION					
1911	6	1350	No record	12.31	75
1912	11	794	" "	13.40	80
1913	72	700	17.1	14.62	86
1914	42	509	6.7	14.74	85
SAMPLES GROWN AT WILLISTON SUB-STATION					
1909	2	942	No record	14.95	79
1910	3	590	13.8	20.10	82
1911	5	730	14.9	15.80	79
1912	4	944	21.3	16.50	83
1913	2	1051	16.3	14.45	82
1914	22	590	16.0	19.00	87
SAMPLES GROWN AT EDGELEY SUB-STATION					
1911	1	950	No record	13.00	75
1912	1	596	11.3	13.30	76
1914	30	800	14.7	15.40	82

TABLE NO. XI.
COMPARISON OF ANALYSES OF VARIETIES FOR 1913 AND 1914—ALL SAMPLES REPORTED.

Name of Variety	1913				1914			
	Number Samples Represented	Per Cent Sugar in Beet	Per Cent Purity	Average Weight Beets (Grams)	Number Samples Represented	Per Cent Sugar in Beets	Per Cent Purity	Average Weight Beets (Grams)
Klein Wanzleben, Old Type.....	4	14.60	82	690	11	16.36	86	686
Klein Wanzleben, Pioneer.....	12	14.95	86	633	13	16.10	84	608
Klein Wanzleben, Original.....	6	15.40	84	651	9	18.15	87	499
Wohanka, Z. R.....	14	15.40	86	661	9	17.82	83	588
Wohanka, E. R.....	8	16.01	88	751	8	15.90	84	645
Schreiber.....	10	14.02	80	772	9	15.03	82	743
B. & L. Productive No. 2.....	24	14.87	83	662	12	16.41	82	724
Terra.....	5	13.94	84	665	18	15.20	82	799
Mette's Elite.....	6	14.55	85	700	3	14.23	83	493
Schobbert's Specialty.....	7	14.43	86	756	3	14.27	83	507
Schobbert's Ideal.....	7	15.57	84	746	3	15.07	87	504
Dippe.....	8	13.32	81	938	3	14.66	87	545
Royal Dutch.....	5	14.52	83	798	3	14.53	86	502

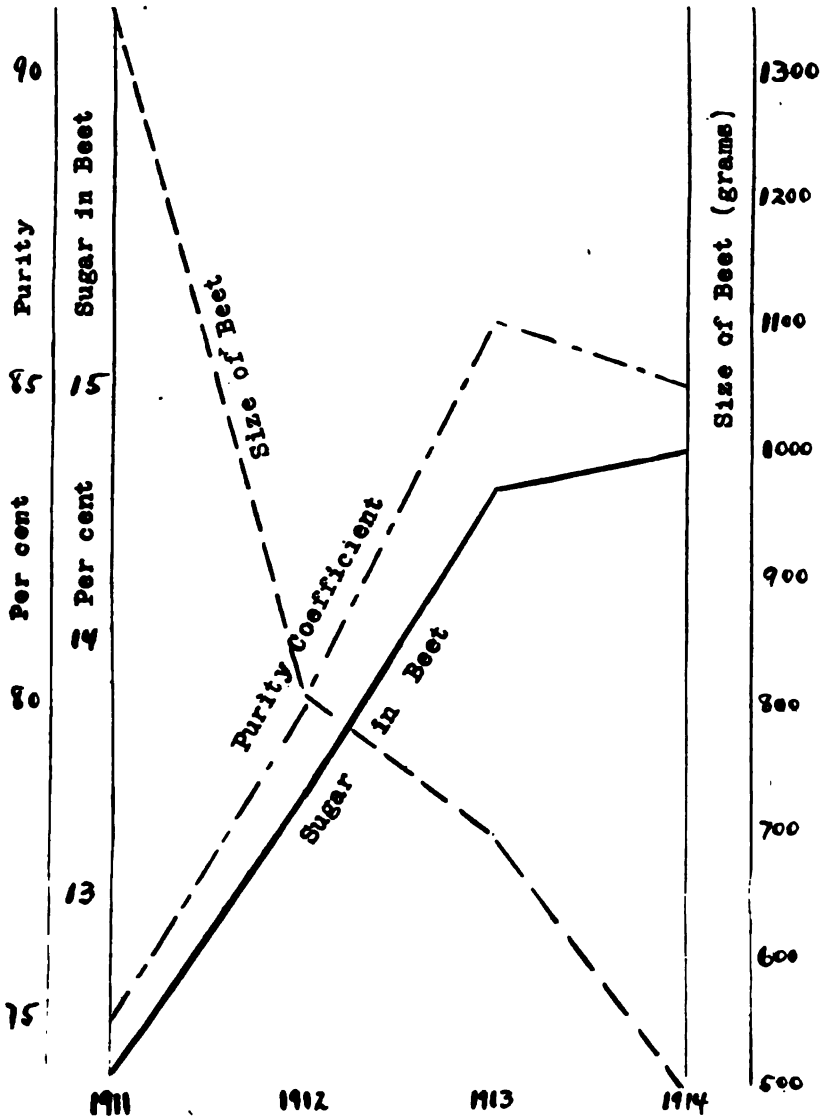


Figure 4.

Fig. 4—Relation of the size of beets to sugar content and coefficient of purity of the samples from North Dakota Experiment Station, 1911-1914.

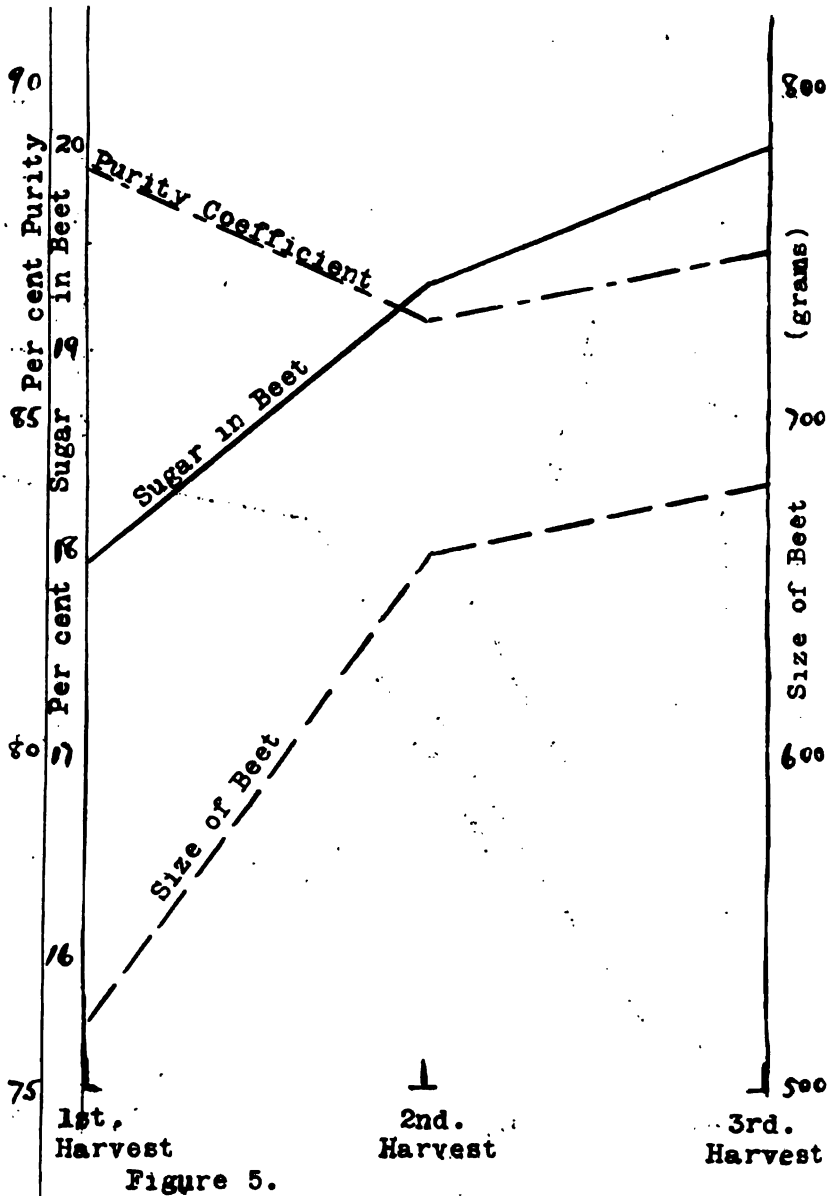


Fig. 5—Relation of the size of the beets to sugar content and purity coefficient at the Williston Sub-station, for the three dates of harvesting, 1914.

TABLE NO. XII.
SUMMARY OF ALL SUGAR BEET ANALYSES REPORTED FOR NORTH DAKOTA.

	Number of Trials	Average Per Cent Sugar	Average Per Cent Purity Coefficient
1891.....	129	11.43	....
1896.....	15	14.38	79
1899.....	82	12.90	78
1900.....	49	9.81	65
1903.....	6	13.40	74
1907.....	3	13.30	....
Average of first period (1891 to 1907)	284	11.79	74
1908.....	20	14.30	83
1910.....	7	16.30	79
1911.....	20	14.56	76
1912.....	54	14.04	80
1913.....	176	14.75	82
1914.....	106	15.94	84
Average of second period (1908 to 1914)	383	14.95	82
Grand Total.....	667	13.61	79

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Chemical and Physical Constants for Wheat and Mill
Products

By E. F. Ladd

Bulletin No. 114

Agricultural College, North Dakota
JANUARY 1916

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* Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

CHEMICAL AND PHYSICAL CONSTANTS FOR WHEAT AND MILL PRODUCTS

By E. F. Ladd*

The State Law enacted in 1905 makes it the duty of the Experiment Station "to conduct experiments and determine the comparative milling values of the different grades of wheat by making chemical analyses of the different grades of wheat and baking tests of the flours made therefrom. A record shall be kept and published of the different grades of wheat, by whom graded, and the person from whom received, with the address, the nature of the soil, previous cropping, etc." The enactment of this law was secured through the efforts of Congressman Geo. M. Young, while he was State Senator.

In accordance with this provision of the Law experiments were undertaken, and from 1907, when the regular milling tests were first made, to 1914 inclusive, some 660 complete trials were carried out on North Dakota grown wheat to enable us to gather data both with regard to the several varieties of wheat generally grown in the state

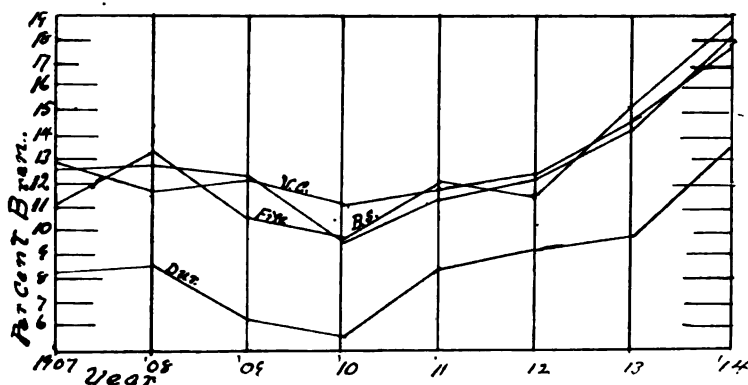


Fig. 1. Showing per cent of wheat bran for the several varieties of wheat for eight years.

and as to the climatic and soil influences on the value of the wheat for milling and baking purposes. The real value of the product must ultimately be determined by the demands of the consumer as expressed in his choice and his willingness to pay a reasonable price for the

*For the chemical, milling and baking data contained in this article I am indebted to my associates, especially T. Sanderson, Levi Thomas, W. L. Stockham and earlier workers in the Department, Prof. H. L. White, L. A. Fitz, and C. H. Bailey. For the presentation of the data the writer alone is responsible.

**Note: This article contains data gathered as the "Joint Co-operative Work of the Experiment Station and the Office of Grain Sandardization of the United States Department of Agriculture."

article. The great mass of data cannot well be presented and, at best, we can only, at this time, present a compilation or summary, otherwise, the whole mass becomes confusing in any attempt at presentation of figures for each individual test.

In a general way we can present studies for the several varieties, especially for Fife, Bluestem, Velvet Chaff and Durum. Marquis and Winter wheat can hardly be compared since our first studies with Marquis wheat began in 1913 and were continued through 1914 for 26 samples, so there cannot be considered the wide range for seasonal changes, and the results, therefore, are only comparable for the two years.

SCREENINGS

The total amount of screenings for the wheat crop in North Dakota amounts, in a single year, to an enormous quantity. In 1892 the writer pointed out in Bulletin No. 8, that the data gathered from 64 samples of wheat taken at elevators, reported a dockage of 2.85%. From 1907 to the close of 1914 there were tested at the Mill, for the purpose of determining the screenings, 652 samples. The loss in cleaning may be summarized for the wheat as received from the farmers, as follows:

SCREENINGS

Average	652 samples.....	3.99
Minimum	652 samples.....	0.00
Maximum	652 samples.....	38.20

These screenings were composed of shrunken and broken kernels of wheat, dirt, weed seed, wild oats, etc. There were 39 samples that showed a loss above 10% in cleaning, and of these 6 ranged between 20% and 30% loss; 83 samples were above 30%. Taking these figures as they stand, the amount of screenings in a crop of 100,000,000 bushels would be 239,400,000 pounds, or 119,700 tons. For these screenings when shipped with the wheat to the market, the grower receives not only no pay, but he must pay the freight on the material to the terminal elevator or market. This material retails to the farmer at above \$20.00 per ton, at which price the screenings as indicated would bring \$2,394,000 for a single year's crop. They job screenings at about \$12.00 to \$15.00 per ton. The feeding value of these screenings, as determined from analysis, shows that they are a valuable stock feed.

ANALYSIS OF SCREENINGS

Water-Free

	Percent.
Ash	5.45
Ether extract (fat)	5.18
Protein (Nx6.25)	17.69
Crude fibre	14.36
Nitrogen free extract	57.32
Total	100.00

LOSS IN MILLING

The average loss in milling for 665 trials, representing all classes and grades of wheat, showed 2.24%. Sometimes there was a slight gain; and the heaviest loss was 8.28%. This, therefore, represents the loss which comes to the miller during the transformation of the wheat into the final mill products. Occasionally, there was a gain; the maximum amount of gain being 2.46%, due largely to water absorbed in tempering the wheat. Of the samples tested 56 showed some gain, while 37 samples showed a loss above 5%. The loss in milling is a difficult factor to control and is attributable to several causes,—evaporation of moisture, the hanging-up or clinging to the inside of the spouting

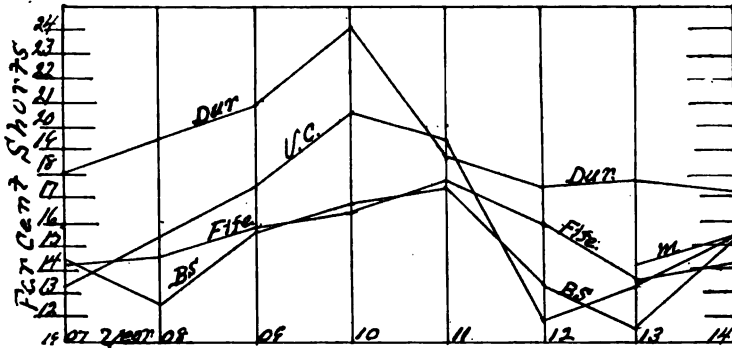


Fig. 2. Showing per cent of shorts produced by the several varieties of wheat by years.

material, and to particles that dust out through cracks and crevices. It has been noticed that the heaviest loss was incurred in milling soft wheats, probably due to the fact that the flour produced was of much softer and fluffier character; therefore, a much larger proportion of it tended to hang-up and was retained in the mill.

FLOUR

The testing of 661 sample of wheat during the period of eight years, all varieties and grades, for the production of flour, showed:

FLOUR FROM WHEAT

Average	Percent 68.82
Maximum	79.41
Minimum	53.21

In the trials 210 samples gave a yield of flour of 70% or better, and 5 samples gave a yield below 60%.

If we summarize our results according to the varieties of wheat for the same period, we find, for the two years under trial, that Marquis gave a slightly higher per cent (71.04%) of flour; and for the eight years Velvet Chaff averaged the lowest, or 67.11%. The per cent of flour for Durum was 69.01%, while that for Fife was 69.60,

and Bluestem 69.78. Therefore, so far as the total per cent of flour is concerned, there is a marked difference between the several varieties of wheat under trial for the series of years, while a study of the grades will show somewhat different results.

WHEAT BRAN

We have data for 649 samples for all classes of wheat, showing an average of 12.71% of bran; the maximum per cent for these trials was 23.23, and the minimum 2.90%. There were 13 samples that gave above 20% of bran and 150 samples gave less than 10% of bran. The amount of bran, therefore, in a 100,000,000 bushel crop would amount to 381,300 tons.

SHORTS

In our trials there were 651 tests of the several varieties and grades of wheat for the same period which gave an average of 15.15% of shorts; a maximum of 23.63%; and a minimum of 7.70%. In these trials 84 samples ranged from 20% to 30%, and 10 samples averaged

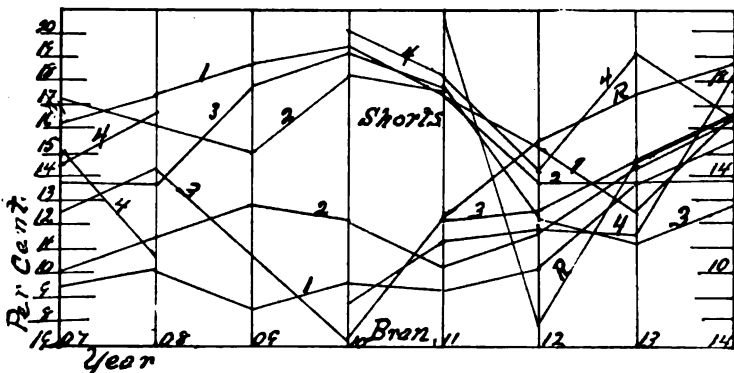


Fig. 3. Showing per cent of Bran and Shorts by grades for all varieties of wheat by years.

less than 10% of shorts. From 100,000,000 bushels of wheat there would be produced 450,500 tons of shorts when the averages are used in calculation.

LOAF VOLUME

In the baking trials upon 646 samples of flour, produced from all classes and varieties of wheat, for the years 1907 to 1914 inclusive, the average loaf volume was 2343 cubic centimeters; a maximum of 2910 c. c., and a minimum of 1510 c. c. Only 12 samples out of 646, however, showed a yield of less than 1800 c. c. for loaf volume.

TABLE I. SHOWING PERCENT OF MILL PRODUCTS PRODUCED BY THE SEVERAL VARIETIES

Variety	Number of Samples	Percent Produced of			Loaf Volume-c. c.
		Flour	Bran	Shorts	
Fife	75	69.60	12.35	15.60	2373
Bluestem	325	69.78	13.93	13.93	2419
Marquis	26	71.04	15.15	14.73	2499
Velvet Chaff	59	67.11	12.80	17.27	2398
Winter Wheat	38	69.86	13.69	14.33	2295
Durum	127	69.01	8.76	19.14	2071

MILL PRODUCTS

Beginning with 1907 numerous milling tests were made with the several varieties of wheat most generally grown in this state, showing yields for the several years, for flour, bran and shorts and for varieties as indicated in the table.

It is interesting to note that in general the per cent of flour produced from the several brands follows the same general curve; that is, the variation in the per cent of flour seems to be due more largely to climatic or seasonal differences than to variety differences. The diagram for the per cent of flour produced for the several varieties clearly indicates this. In general Velvet Chaff produced a lower per cent of flour than any of the varieties, although at the same time it produced the maximum per cent. There is very little difference between the Fife and Bluestem, and it is interesting to note that for the period of eight years Durum wheat has averaged only slightly lower in per cent of flour than the other varieties. In general there were

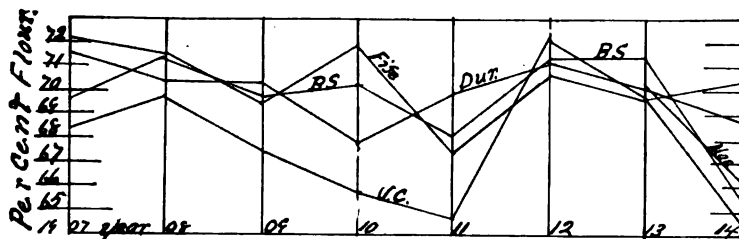


Fig. 4. Showing per cent of flour yielded for each variety of wheat by years.

samples enough for the entire period to get fair averages for the several varieties, but not in all instances for the several grades of the different varieties. The 75 samples of Fife gave an average of 69.82%; the 325 samples of Bluestem gave an average of 69.59%; while the general average by years can best be shown in a table.

TABLE II. MILL PRODUCTS FOR VARIETIES BY YEARS

	Fife		Bluestem		Winter Wheat		Velvet Chaff		Durum	
	No. of Samples	% Flour	No. of Samples	% Flour	No. of Samples	% Flour	No. of Samples	% Flour	No. of Samples	% Flour
1907										
Flour	5	72.05	9	69.51	2	64.40	2	68.30	17	71.52
Bran	5	11.17	9	12.62	2	11.50	2	12.90	17	8.18
Shorts	5	14.01	9	14.27	2	18.55	2	13.31	17	18.01
1908										
Flour	9	71.56	12	71.23	2	69.18	5	69.77	31	70.29
Bran	9	13.50	12	12.69	2	13.40	5	11.88	31	8.62
Shorts	9	14.42	12	12.62	2	15.35	5	15.28	31	19.47
1909										
Flour	13	69.40	11	69.57	.....	.....	3	67.40	18	70.26
Bran	13	10.67	11	12.27	.....	.....	3	12.27	18	6.12
Shorts	13	15.90	11	15.70	.....	.....	3	17.20	18	20.97
1910										
Flour	12	71.90	13	70.19	.....	.....	20	65.74	10	67.95
Bran	12	9.91	13	10.73	.....	.....	20	11.01	10	5.69
Shorts	12	16.45	13	16.66	.....	.....	20	20.73	10	24.00
1911										
Flour	15	67.36	32	68.01	6	68.60	9	64.78	10	69.98
Bran	15	12.02	32	11.33	6	11.00	9	11.89	10	8.46
Shorts	15	17.79	32	17.42	6	19.00	9	19.37	10	18.93
1912										
Flour	7	70.72	84	71.29	3	68.98	2	73.06	13	71.13
Bran	7	11.51	84	12.10	3	12.13	2	12.25	13	9.16
Shorts	7	15.00	84	13.29	3	17.55	2	11.95	13	17.42
1913										
Flour	6	69.77	104	71.36	14	72.46	12	69.97	13	70.03
Bran	6	15.10	104	14.76	14	14.04	12	14.33	13	9.93
Shorts	6	13.60	104	11.57	14	12.17	12	13.34	13	17.62
1914										
Flour	8	65.79	60	65.54	9	68.52	6	64.72	15	68.93
Bran	8	18.78	60	17.83	9	16.88	6	18.05	15	13.76
Shorts	8	14.05	60	16.14	9	13.98	6	15.18	15	17.28
Marquis Wheat										
1913										
Flour	13	70.79								
Bran	13	13.47								
Shorts	13	14.08								
1914										
Flour	13	66.33								
Bran	13	16.83								
Shorts	13	15.37								

MILLING TESTS BY GRADES

Tests have been made to show the various per cents of mill products which are secured in the several varieties of wheat, although in mill practice the varieties are usually blended together according to grade and, at times, the grades are mixed, but for convenience, as giving instructive information, I am tabulating the results by years, according to the grade of wheat, without regard to variety, showing the number of samples milled and the per cent for the several grades, also, the bran and shorts for the same period.

TABLE III. FLOUR AVERAGES BY GRADES OF WHEAT

Year	Grade 1		Grade 2		Grade 3		Grade 4		Grade Rejected	
	No. of Samples	% Flour	No. of Samples	% Flour	No. of Samples	% Flour	No. of Samples	% Flour	No. of Samples	% Flour
1907	19	71.84	11	70.20	4	68.97	1	64.57	----	-----
1908	45	70.79	11	70.50	2	67.78	1	68.34	----	-----
1909	31	70.28	8	67.63	6	69.88	----	-----	----	-----
1910	49	68.76	5	66.85	2	70.75	1	65.60	----	-----
1911	17	70.65	19	68.28	19	66.87	11	66.19	6	64.07
1912	32	69.09	20	71.54	51	71.16	5	68.49	1	74.54
1913	102	71.22	44	71.20	13	70.88	1	66.47	2	67.17
1914	20	68.74	17	67.95	18	69.03	39	64.74	17	62.87
Avr.		70.12		69.21		69.41		67.33		66.91

BRAN AVERAGES BY GRADES OF WHEAT

1907	19	9.50	11	10.07	4	12.73	1	15.25	----	-----
1908	45	10.00	11	11.44	2	14.30	1	11.90	----	-----
1909	31	8.50	8	12.95	6	10.60	----	-----	----	-----
1910	49	9.63	5	12.02	2	7.10	1	8.90	----	-----
1911	17	9.21	19	10.26	19	12.14	11	12.30	6	12.22
1912	32	10.11	20	11.74	51	12.55	5	12.80	1	15.70
1913	102	13.96	44	14.44	13	14.83	1	12.70	2	17.60
1914	20	14.53	17	16.37	18	16.54	39	18.43	17	18.86

SHORTS AVERAGES BY GRADES OF WHEAT

1907	19	16.31	11	17.09	4	13.98	1	14.66	----	-----
1908	45	17.86	11	16.06	2	13.85	1	16.68	----	-----
1909	31	18.72	8	15.05	6	17.96	----	-----	----	-----
1910	49	19.56	5	18.08	2	19.05	1	20.00	----	-----
1911	17	17.56	19	17.50	19	17.76	11	18.29	6	20.63
1912	32	15.23	20	13.81	51	13.18	5	14.14	1	7.80
1913	102	12.71	44	11.94	13	12.12	1	19.10	2	14.55
1914	20	16.59	17	13.94	18	13.92	39	16.44	17	17.74

MOISTURE IN WHEAT BEFORE AND AFTER TEMPERING; ALSO
IN FLOUR

In 1907 records were not kept as to the per cent of moisture in wheat before or after tempering, but for the other years we have full

data. For all varieties and grades for the seven years it was found that the average before tempering wheat was 13.09% of moisture. The

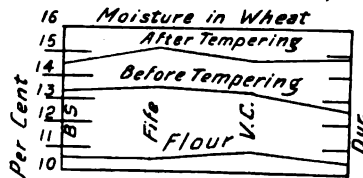


Fig. 5. Showing average per cent of moisture in wheat before and after tempering, also in flour from same.

average after tempering was 14.82%, or there was a gain of 1.73 per cent of moisture due to the process of tempering. It is interesting

TABLE IV. PERCENT OF WATER IN WHEATS AND FLOURS

	Bluestem	Fife	Velvet Chaff	Durum
Wheat before tempering	13.07	13.48	13.14	12.72
Wheat after tempering	14.49	15.10	14.70	14.99
Flour, percent	10.54	10.53	10.92	10.46

to note that the flour produced from these same samples showed an average of 10.61% of moisture.

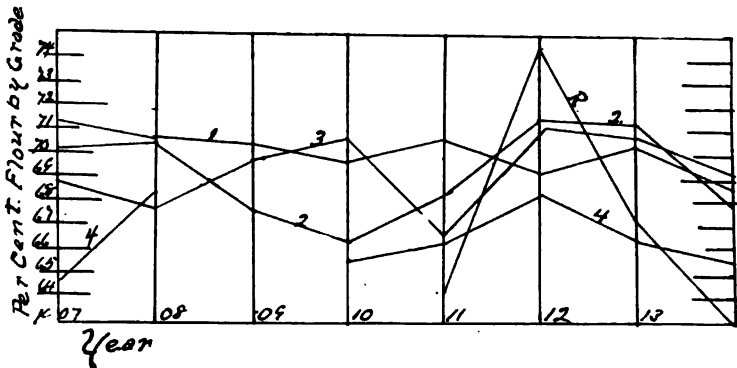


Fig. 6. Diagram showing per cent of flour for each grade of wheat all varieties combined by years

The average per cent of moisture for the several years and the different varieties is shown in the table:

TABLE V. PERCENT OF MOISTURE IN WHEAT BEFORE TEMPERING

Year	Bluestem	Fife	Velvet Chaff	Durum
1908	11.51	12.5	12.8	10.75
1909	12.85	13.13	13.2	11.11
1910	12.75	13.95	14.03	14.65
1911	13.76	14.07	13.20	14.05
1912	14.05	15.20	13.45	13.13
1913	13.20	12.82	12.79	13.18
1914	13.17	12.72	13.02	12.77
Average	13.07	13.48	13.14	12.72

PERCENT MOISTURE IN WHEAT AFTER TEMPERING

1908	13.52	15.20	.....	14.96
1909	14.75	13.90	14.00	13.87
1910	13.45	14.80	15.30	15.70
1911	14.92	15.33	14.28	15.54
1912	15.13	16.43	14.70	14.70
1913	14.71	14.67	14.17	14.87
1914	14.99	15.39	15.75	15.35
Average	14.49	15.10	14.70	14.99

PERCENT MOISTURE IN THE FLOUR

1907	7.47	7.13	8.19	7.64
1908	9.72	9.17	9.84	10.00
1909	11.47	11.38	11.25	11.20
1910	11.33	11.51	11.89	11.13
1911	10.47	11.06	11.17	10.80
1912	11.07	10.93	11.41	10.44
1913	11.48	11.07	11.22	11.52
1914	11.37	11.97	12.44	10.87
Average	10.54	10.53	10.92	10.46

PROTEIN IN WHEAT

The amount of protein (Nx6.25) in the several varieties of wheat for the eight years, 1907 to 1914 inclusive, shows not a wide range for the several varieties in the same grade.

TABLE VI. PERCENT PROTEIN IN WHEAT

Variety	Grade No.1	Grade No.2	Grade No.3	Grade No.4	Rejected	Mean
Bluestem	14.41	13.25	15.69	14.76	14.72	14.56
Fife	14.54	14.55	16.29	14.32	12.69	14.48
Velvet Chaff	14.21	12.56	14.59	.....	14.84	14.05
Durum	14.39	16.27	16.16	14.52	.....	15.33
Average	14.38	14.15	15.68	14.53	14.08	14.60

The average per cent of protein for all the samples of wheat is 14.60%, while the maximum per cent was 16.29 per cent for grade No. 3 Fife wheat, and the minimum per cent was 12.56 for Grade No. 2 Velvet Chaff.

PROTEIN IN FLOUR

Determinations made of protein in some 600 odd samples of the several grades of wheat, and the amount of protein when nitrogen was multiplied by 6.25, showed as follows:

TABLE VII. PROTEIN IN FLOUR

Variety	Grade No.1	Grade No.2	Grade No.3	Grade No.4	Rejected	Mean
Bluestem	13.25	12.95	14.32	13.88	13.93	13.46
Fife	13.63	13.12	15.04	13.55	11.69	13.14
Velvet Chaff	12.77	11.56	13.32	.....	12.44	14.45
Durum	14.52	14.89	15.32	13.82	.....	13.76
Mean of all	13.12	13.19	14.45	13.78	13.06	13.70

The difference, therefore, in the per cent of protein found in the flour made from the several grades of wheat does not materially differ.

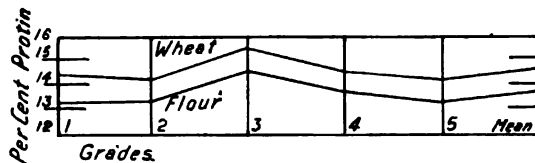


Fig. 7. Showing per cent of protein in the several grades of wheat all varieties and in the flour.

and the average for all the grades and varieties was 12.78%, while the per cent of protein in the wheat averaged for all varieties and grades 14.60, or, for the flour 1.82% lower than the average for all the wheats from which the flour was produced.

Taken as a whole, Velvet Chaff showed a lower per cent of protein than either of the other varieties, while the Durum averaged somewhat higher.

No direct relationship can be traced to seasonal differences, although in different seasons the several varieties have shown a difference in total protein. In this study no attempt is made to differentiate between the different types of gluten constituents in the flour.

TABLE VIII. PROTEIN IN WHEAT BY GRADES AND YEARS

BLUESTEM—PERCENT PROTEIN—NK6.25					
Year	Grade No. 1	Grade No. 2	Grade No. 3	Grade No. 4	Rejected
1907	12.09	14.78	13.12	13.37	.....
1908	12.82	11.39	16.56	.....	.....
1909	13.21	11.94	16.66	.....	.....
1910	13.89	.....	13.31	.....	.....
1911	13.52	13.14	14.10	14.36	14.62
1912	14.06	14.09	14.70	14.78	14.00
1913	13.17	12.48	12.60	.....	.....
1914	.....	12.84	13.50	13.02	13.18
Average	13.25	12.95	14.32	13.88	13.93

FIFE					
1907	12.59	12.50	15.50	.....	.....
1908	14.78	10.06	15.25	.....	.....
1909	14.45	12.67	15.25	.....	.....
1910	14.66	15.87	.....	.....	.....
1911	13.36	.....	14.39	15.14	.....
1912	12.69	13.81	.....	.....	.....
1913	12.84	13.81	.....	.....	.....
1914	.....	.....	14.81	11.97	11.69
Average	13.63	13.12	15.04	13.55	11.69

VELVET CHAFF					
1907	11.81	.....	.....	.....	.....
1908	13.04	11.00	.....	.....	.....
1909	15.06	.....	12.31	.....	.....
1910	13.33	12.04	.....	.....	.....
1911	.....	10.75	13.09	.....	12.63
1912	13.50	.....	13.00	.....	.....
1913	12.05	12.44	12.81	.....	12.25
1914	10.63	11.57	15.38	.....	.....
Average	12.77	11.56	13.32	.....	12.44

DURUM					
1907	12.65	12.06	.....	.....	.....
1908	15.46	13.92	.....	11.13	.....
1909	15.24	.....	18.25	.....	.....
1910	16.45	.....	17.31	14.88	.....
1911	16.16	16.31	.....	.....	.....
1912	12.89	17.69	13.12	.....	.....
1913	14.24	13.10	13.75	15.44	.....
1914	13.13	16.31	14.19	.....	.....
Average	14.52	14.89	15.32	13.82	.....

COLOR

The color of flour is of importance as the housewife and the baker give preference to a flour for bread-making which is decidedly white. In fact, the public have come to judge the quality of flour by certain physical appearances, and thus, may for a time be misled when these usually recognized characteristics have been obliterated, or other less choice articles have been made to appear like the genuine product. Color is expressed on the empirical scale, ranging from 50 to 100 or above. Anything below 50 is considered as being below a low grade, and usually goes to the reddog flour or with the middlings. The whiter the color, the higher the color score; the darker flours receiving lower scores, depending upon the depth of the color.

When bleaching by means of nitrogen peroxide was practiced the housewife was for a time misled, but even before bleaching came to be prohibited by the State, chemically treated or bleached flour was coming to be discredited by many intelligent housewives and tabooed by the expert baker. On the other hand, so long as big profits could be wrung from the consumer the owners of the patents were willing to spend freely of their profits. The real reason for bleaching at all seems to be well expressed by Dr. Otto Folin of Harvard University in his work on "Preservatives and Other Chemicals in Foods," when he says:

"The addition of dangerous chemicals to food products for no other purpose than to hide inferiority is a practice which, from the standpoint of the consumer, has nothing to recommend it. Take for example the notorious case of bleached flour which has been before the courts for the last four years. One of the natural and more or less reliable indexes to the baking quality of flour is its color. The only purpose of the bleaching was to make the flour from dark wheat look as white as the best patent flour. To accomplish this purpose had been the aim of commercial chemists for many years, and they finally succeeded. The reward for their success was contributed by the consumers of the bleached flour at the rate of from fifty cents to a dollar extra per barrel.

"This 'artificially aged' flour, as its owners and defenders liked to call it, was produced by mixing the flour with a very poisonous gas called nitrogen peroxide. The flour absorbed this gas as a sponge absorbs water and instantly became white. The millers themselves, and in fact the leading attorney for the millers, had probably never been thoroughly informed as to the nature of their bleaching process. The nitrogen peroxide which they used was prepared in their mills electrically, and they endeavored to make out that they had simply mixed the flour with air which had been electrically purified, somewhat in the same way as a thunderstorm is held to purify the atmosphere. What they were really using, however, was nitrogen peroxide, which is equivalent to a mixture of nitric acid and nitrous acid, both very poisonous. The addition of the bleaching agent had to be regulated with great care, for if too much was introduced the flour turned yellow and became wholly unfit for food. This fact was interpreted by the promoters of the process and their attorneys as a natural and effective protection for the consumer."

Other methods for treating flour are promoted, it would seem, for no other purpose than that which prompted the bleaching of flour.

Not one of these methods or devices contributes in any part to the real milling problem, and while being promoted from the office end are not at all commended by the real expert miller. Sooner or later all deceptive subterfuges will be prohibited, although many of them will for a time at least have a run only to work injury in the end.

The color score for bread made from the several varieties of flour ranged as follows:

COLOR SCORE

	Color Percent
Bluestem	94.56
Fife	95.50
Velvet chaff	94.49
Durum	91.00
Mean for all	93.94

The Durum has more of the yellow and less of the white, but this does not necessarily indicate a lower food value for the Durum than for Fife or Bluestem flours; in fact, the gluten or protein content is greater for the Durum than for the other hard spring wheat flours.

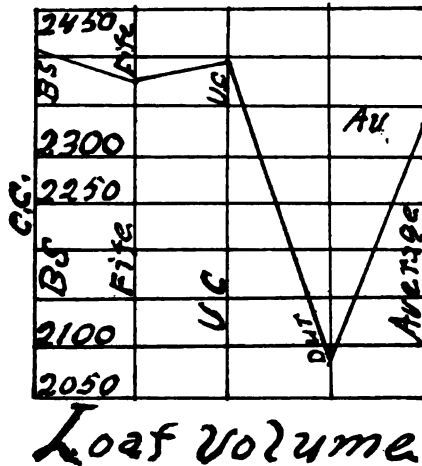


Fig. 8. Showing average loaf volumes for bread from flours of different varieties of wheat.

RECEIPTS AND SHIPMENTS OF NORTHERN SPRING WHEAT BY GRADES

Minneapolis Elevators, Sept. 1, 1910 to Aug. 31, 1912.

As indicating the proportion of the several grades of wheat which found its way to the market, the following table from the report of the Chief Inspector of Grain for Minnesota will be found of interest and probably will serve as a safe guide to the proportion of the several grades coming upon the market.

Grade	Received* (bus.)	Shipped (bus.)
No. 1 Hard	586,600	276,484
No. 1 Northern	15,571,575	19,978,777
No. 2 Northern	20,413,584	22,242,410
No. 3 Northern	9,770,031	7,864,232
No. 4 Northern	2,812,653	624,433
Rejected	1,175,513	621,773
No grade	4,695,565	1,000,945
Total	55,025,521	52,409,054

*Receipts included amounts on hand at the beginning of the period, and shipments included amounts on hand at the end of the period. The omission of Durum and Winter wheats in the table renders the totals of receipts and shipments non-comparable.

If we calculate the per cent in the foregoing for each of the grades as received and shipped out, we shall have as follows:

TABLE IX. GRADES OF WHEAT RECEIVED AND SHIPPED OUT

Grade	As Received Percent	Shipped out Percent
No. 1 Hard	1.0	0.5
No. 1 Northern	28.3	38.1
No. 2 Northern	37.1	42.4
No. 3 Northern	17.7	14.6
No. 4 Northern	5.1	1.2
Rejected	2.1	1.1
No grade	8.5	1.9
Total	99.8	99.8

The results not being carried out in full there is a loss of 0.2% in each case and this is not considered in our calculations.

At the prices which we have already named for wheat, for the several grades, with the exception of "no grade," we should have for the grades as received the following values; and if we assume that "no grade" would bring 80 cents per bushel, no injustice would be done as the price is probably greater than that which has been paid for the wheat.

TABLE X. VALUE OF WHEAT AT MINNEAPOLIS ELEVATORS

Grade	Wheat Received		Price per Bushel		Value
No. 1 Hard	586,000	x	\$1.06	=	\$ 620,560
No. 1°	15,571,575	x	1.0167	=	15,831,621
No. 2°	20,413,584	x	0.9847	=	20,101,256
No. 3°	9,770,031	x	0.9663	=	9,440,780
No. 4°	2,812,653	x	0.9092	=	2,557,264
Rejected	1,175,513	x	0.8531	=	1,002,831
No Grade	4,695,565	x	0.80	=	3,756,452
	55,025,521		Total		\$ 53,310,764

TABLE X. (Cont.) VALUE OF WHEAT AT MINNEAPOLIS ELEVATORS

Grade	As Shipped out		Price per Bushel		Value
No. 1 Hard	276,484	x	1.06	=	293,073
No. 1°	19,978,777	x	1.0167	=	20,312,422
No. 2°	22,242,410	x	0.9847	=	21,902,101
No. 3°	7,664,232	x	0.9663	=	7,405,947
No. 4°	624,433	x	0.9092	=	567,784
Rejected	621,778	x	0.8531	=	530,434
No. Grade	1,000,000	x	0.80	=	800,000
	52,409,054*		Total		\$ 51,811,711

*There still remains unsold, according to the report, 2,616,464 bushels of wheat the grade for which is not given. If this should average no better than No. 3 its value would be \$2,528,289. The amount then received would be \$54,340,000, or a gain of \$1,029,236 exclusive of any increase in the selling price over the purchase cost of the wheat.

Let us assume again that North Dakota markets 100,000,000 bushels of wheat and that the wheat as received and sold from the elevators should be for the same per cent and for the same price per bushel as in the foregoing. What would be the difference for the product?

Grade	Bu. Wheat Received		Price per Bushel		Value
No. 1 Hard	1,000,000	x	\$1.06	=	\$ 1,060,000
No. 1°	28,800,000	x	1.0167	=	28,772,610
No. 2°	37,100,000	x	0.9847	=	36,532,370
No. 3°	17,700,000	x	0.9663	=	17,103,510
No. 4°	5,100,000	x	0.9092	=	4,636,920
Rejected	2,100,000	x	0.8531	=	1,791,510
No grade	8,500,000	x	0.80	=	6,800,000
			Total		\$ 96,696,920

In the same way if the grain is mixed and re-graded our results would show as follows:

Grade	Wheat as Received		Price per Bushel		Value
No. 1 Hard	500,000	x	\$1.06	=	\$ 530,000
No. 1°	38,100,000	x	1.0167	=	38,786,270
No. 2°	42,400,000	x	0.9847	=	41,751,280
No. 3°	14,600,000	x	0.9663	=	14,107,980
No. 4°	1,200,000	x	0.9092	=	1,091,040
Rejected	1,100,000	x	0.8531	=	938,410
No grade	1,900,000	x	0.80	=	1,520,000
			Total		\$ 98,674,980

The juggling of the results by a system of mixing and re-grading has increased the selling price by \$1,978,060. This increase has not come from any change or improvement in quality, but rather through a system of mixing and re-grading.

WHEAT FOR A BARREL OF FLOUR

How much wheat will be required of the several varieties to produce a barrel of flour as shown in the milling trials?

TABLE XI. WHEAT FOR A BARREL OF FLOUR

Variety	Per Barrel of Flour	
	Pounds	Bushels
Bluestem	284.8	4.74
Fife	281.6	4.69
Velvet Chaff	290.0	4.83
Durum	284.0	4.73

Tests for Marquis wheat cover only the years of 1913 and 1914, and for the Winter wheat, the same period are compared.

	Winter	Marquis
Pounds	280.5	284.0
Bushels	4.66	4.73

It has taken slightly more of Velvet Chaff wheat than of any of the other varieties to produce a barrel of flour, and least of the Winter wheat; there is essentially no difference between the Bluestem and Durum wheats as to the number of bushels required to produce a barrel of flour.

ABSORPTION OF WATER

The amount of water absorbed by flour in its preparation for bread is an important feature in determining the expansive qualities of the flour or its gluten and, therefore, of the number of loaves of bread per barrel of flour. The average of eight years for flours of all grades from the several varieties of wheat, over 660 samples, was as follows:

WATER ABSORBED

	Percent
Bluestem	57.27
Fife	56.52
Velvet Chaff	55.26
Durum	57.26
Mean of all varieties	56.35

The average for Marquis wheat flour for 1913-1914, only two years under trial, was 58.03%. The range for the several years for the different varieties is not great. Bluestem flour in 1907 averaged 61.60%; in 1902 the average absorption was 56.50%. Velvet Chaff wheat flour showed the lowest absorption, while there is essentially no difference in the averages for the eight years between the Durum and Bluestem flours.

TABLE XII. ABSORPTION OF WATER—PERCENT

Year	Bluestem	Fife	Velvet Chaff	Durum	Mean
1907	61.06	61.18	55.75	59.94	59.48
1908	54.89	54.85	55.19	56.32	55.31
1909	52.14	52.88	49.27	54.10	52.09
1910	52.06	52.13	51.30	50.83	51.58
1911	57.74	55.85	54.23	57.68	56.37
1912	57.20	57.95	55.45	58.62	57.30
1913	59.10	61.30	58.87	60.52	59.97
1914	59.41	57.92	59.33	58.10	58.69
Average	57.27	56.52	55.26	57.26	56.35

Marquis					
1913	57.79				
1914	58.26				

Take Fife wheat flour and the average water absorption for the dough in bread-making for 1910 was only 52.13 per cent, while the same variety in 1913 had an absorption of 61.30 per cent; a difference of 9.17 per cent.

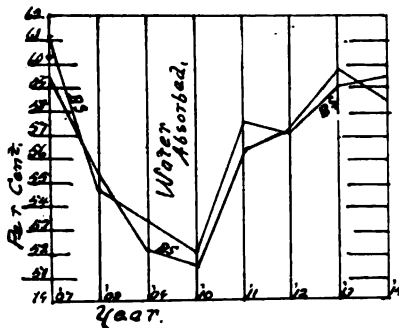


Fig. 9. Diagram showing the average absorption for the several years for all varieties compared with Bluestem Wheat flour.

BREAD PRODUCING QUALITIES

One of the important matters to be considered in connection with the production of flour is as to the character and volume of the bread that can be produced from the same. More than 650 tests divided among the several varieties of wheat and for the different grades of each variety, did not show any very marked variation in loaf volume for the different grades. As a whole the Bluestem averaged slightly higher in loaf volume than either of the others. Velvet Chaff was equal to the Fife, while Durum fell considerably below. The color and texture of all were good. The mean for all the tests of each variety furnishes a fair basis for comparison.

TABLE XIII. LOAF VOLUME AND QUALITY

Variety	Volume c. c.	Color %	Texture %
Bluestem	2419	94.56	94.10
Fife	2373	95.05	94.20
Velvet Chaff	2398	94.49	92.92
Durum	2071	91.00	91.04
Mean for all	2347	93.94	93.18

It is to be noticed that in Velvet Chaff there were no samples that graded No. 4 and only one of the grade rejected, while in Durum there were no samples throughout the eight years which graded as rejected. In other words, these Durum wheats have suffered less from blight, rust, smut and other adverse and climatic conditions than the other varieties of spring wheat.

TABLE XIV. BAKING TEST

Variety and Grade	Volume c. c.	Color %	Texture %
Bluestem, Grade 1	2347	96.87	95.48
Bluestem, Grade 2	2359	96.35	93.10
Bluestem, Grade 3	2456	97.26	95.24
Bluestem, Grade 4	2379	94.56	93.00
Bluestem, Grade Rejected	2558	87.77	93.72
Mean	2419	94.56	94.10
Fife, Grade 1	2385	97.61	95.80
Fife, Grade 2	2226	94.00	93.60
Fife, Grade 3	2436	96.14	94.00
Fife, Grade 4	2630	97.50	95.60
Fife, Grade Rejected	2190	90.00	92.00
Mean	2373	95.05	94.20
Velvet Chaff, Grade 1	2309	96.11	94.63
Velvet Chaff, Grade 2	2353	97.70	94.00
Velvet Chaff, Grade 3	2392	88.17	91.05
Velvet Chaff, Grade 4 .....	.....	.....	.....
Velvet Chaff, Grade Rejected	2540	97.00	92.00
Mean	2398	94.49	92.92
Durum, Grade 1	2031	90.87	91.00
Durum, Grade 2	2033	91.30	90.40
Durum, Grade 3	2047	89.50	91.75
Durum, Grade 4	2174	92.33	91.00
Durum, Grade Rejected .....	.....	.....	.....
Mean	2071	91.00	91.04

WHEAT AND FLOUR PRICES

From the data compiled each season during the period of active marketing of grain for 21 successive days, according to the market as quoted in the Northwestern Miller, the averages for the price of flour, per 100 pounds, for the years 1907 to 1914 inclusive, would be approximately as shown below:

Straight flour	\$ 2.5391
Bran	1.0180
Shorts	1.2429
Screenings	0.5154

PRICE OF WHEAT PER BUSHEL

For this period, covering the same years, 1907 to 1914 inclusive, the average price of wheat, Bluestem and Fife, for the several grades, is used in making the necessary computations.

	Price per bushel
Grade No. 1 Hard	\$ 1.06
Grade No. 1	1.0167
Grade No. 2	0.9847
Grade No. 3	0.9663
Grade No. 4	0.9092
Rejected	0.8531

MILLING AVERAGES

During the same period, from 1907 to 1914, the average for some 660 samples experimentally milled, gives results as shown by the accompanying table:

TABLE XV. AVERAGE MILL PRODUCTS

Grade	Screenings	Flour	Bran	Shorts
No. 1	2.13	70.12	10.68	16.75
No. 2	3.19	69.20	12.41	15.43
No. 3	4.49	69.41	12.59	15.23
No. 4	6.14	66.34	13.18	17.04
Rejected	6.68	67.16	16.09	15.15

Let us assume now that 1,000 bushels of each grade of wheat have been purchased at the prices named for the several grades and marketed as per the figures given above; then, we should have for the 60,000 pounds of wheat, each grade being presented in detail as a separate problem:

GRADE NO. 1 NORTHERN

	Weight	Percent	Pounds	Cents	Value
Flour	60,000	x 70.12	= 42,072	x 2.54	= \$1,068.63
Bran	60,000	x 10.68	= 6,408	x 1.02	= 65.36
Shorts	60,000	x 16.75	= 10,050	x 1.24	= 124.62
Screenings	60,000	x 2.13	= 1,278	x 0.51	= 65.2
Total					= \$1,268.13

GRADE NO. 2 NORTHERN

	Weight	Percent	Pounds	Cents	Value
Flour	= 60,000	x 69.20	= 41,520	x 2.54	= \$1,054.61
Bran	= 60,000	x 12.41	= 7,446	x 1.02	= 75.95
Shorts	= 60,000	x 15.43	= 9,204	x 1.24	= 114.13
Screenings	= 60,000	x 3.19	= 1,914	x 0.51	= 9.76
Total					= \$1,254.45

GRADE NO. 3 NORTHERN

Flour	= 60,000	x 69.41	= 41,646	x 2.54	= \$1,057.81
Bran	= 60,000	x 12.59	= 7,554	x 1.02	= 77.05
Shorts	= 60,000	x 15.23	= 9,138	x 1.24	= 113.31
Screenings	= 60,000	x 4.49	= 2,694	x 0.51	= 13.74
Total					= \$1,261.91

GRADE NO. 4 NORTHERN

Flour	= 60,000	x 66.34	= 39,804	x 2.54	= \$1,010.92
Bran	= 60,000	x 13.18	= 7,908	x 1.02	= 80.66
Shorts	= 60,000	x 17.04	= 10,224	x 1.24	= 124.78
Screenings	= 60,000	x 6.14	= 3,684	x 0.51	= 18.79
Total					= \$1,235.15

GRADE REJECTED

Flour	= 60,000	x 67.16	= 40,296	x 2.54	= \$1,023.52
Bran	= 60,000	x 18.09	= 9,654	x 1.02	= 98.47
Shorts	= 60,000	x 15.15	= 9,090	x 1.24	= 112.71
Screenings	= 60,000	x 6.68	= 4,008	x 0.51	= 20.44
Total					= \$1,255.14

COST OF WHEAT

If for the several grades we first deduct the amount of screenings from the total weight and convert into bushels, we shall have for the several grades the number of bushels of each grade of wheat to be milled.

TABLE XVI. BUSHELS OF CLEAN WHEAT IN EACH GRADE

Grade	Weight	Screenings	Clean Wheat	Bushels
No. 1	= 60,000	= 1,278	= 58,722	= 978.7
No. 2	= 60,000	= 1,914	= 58,086	= 968.1
No. 3	= 60,000	= 2,694	= 57,306	= 955.1
No. 4	= 60,000	= 3,684	= 56,316	= 938.6
Rejected	= 60,000	= 4,008	= 55,992	= 933.2

Now we may compare the cost for the wheat at the average prices for which the grades are purchased, with the receipts and our results may be easily compared.

TABLE XVII. COSTS AND RECEIPTS FOR EACH GRADE

	Grades No. 1°	No. 2°	No. 3°	No. 4°	Rejected
Cost	\$1016.70	\$984.70	\$966.30	\$909.20	\$853.10
Total receipts	1268.13	1255.12	1261.91	1235.15	1255.14
Gain	\$251.43	\$270.42	\$295.61	\$325.95	\$402.04

In other words then, in the purchase of 60,000 pounds of the several grades of wheat at a cost as indicated, the gains for the expenditures are readily compared.

TABLE XVIII. GAIN IN RELATION TO COST

	Grades No. 1°	No. 2°	No. 3°	No. 4°	Rejected
Cost	\$1016.70	\$984.70	\$966.30	\$909.30	\$853.10
Gain	251.43	270.42	295.61	325.95	402.04

It will readily be observed that for each expenditure of \$1016.70 for Grade No. 1, there is a gain of \$251.43; or, the gain for the transforming of wheat into flour has been \$251.43; and for the lowest expenditure of \$853.10, a gain of \$402.04. In other words, then, assuming that the profits are reasonably fair for the best grade of wheat, there is a much larger profit for milling and selling the rejected and lower grades of wheat. In other words, again, as we have pointed out in a previous bulletin (Volume 3, No. 14 Food Department) it would seem that the present system of grading wheat can hardly be classed as equitable under market conditions for mill products as they now prevail.

Now that we have considered the cost and gain for 1,000 bushels of each grade of the several wheats, let us see what the receipts are for each 1,000 bushels for the several grades.

TABLE XIX. RECEIPTS FOR EACH GRADE

	Grades No. 1°	No. 2°	No. 3°	No. 4°	Rejected
Receipts	\$1268.13	\$1255.12	\$1261.91	\$1235.15	\$1255.14

The average receipts for the five grades above would be \$1255.09. In other words, the receipts for the rejected wheat were greater than the general average by 5 cents; and Grade No. 1 was greater by only \$13.04, while Grade No. 2 was 3 cents above the general average. The gain, therefore, in transforming the several grades of wheat into commercial mill products and marketing the same when expressed in per cent, was as follows:

GAINS IN PERCENT

Grade	Percent
No. 1	24.84
No. 2	27.39
No. 3	30.59
No. 4	35.85
Rejected	47.13

In other words, the percentage gained on the rejected wheat was nearly twice that for Grade No. 1 Northern.

Let us see again what would have been the cost, receipts and gains, had a mill purchased 1,000 bushels of each of the several grades or a total of 5,000 bushels, and transformed the same into mill products at the prices already indicated for the several grades.

TABLE XX. COSTS AND RECEIPTS FOR WHEAT

Grade	1,000 Bushels of Each Grade		
	Cost	Receipts	Gain
Grade No. 1	\$1016.70	\$1268.13	\$251.43
Grade No. 2	984.70	1255.12	220.42
Grade No. 3	966.30	1261.91	295.61
Grade No. 4	909.20	1235.15	325.95
Grade Rejected	850.10	1255.14	402.04
Total	\$4730.00	\$6275.45	\$1545.45

The total cost would have been \$4730.00, while the receipts for the various mill products would have amounted to \$6275.45, and the gain for transforming these products would have been \$1545.45. This, therefore, would give us as the average cost for each 1,000 bushels of wheat in this mixture \$946, an average receipt of \$1255.09, and an average gain of \$309.09, or an average profit of 32.67 per cent.

If we assume that there was a reasonable profit in milling No. 1 Northern wheat, then the profit is out of proportion for No. 4 and rejected grades, and therefore, the grading is not equitable for all classes of wheat. On the other hand, if we assume that the profits for milling the 5,000 bushels of mixed wheat were just, then we must admit that the system of grading is not equitable and that there should be a re-adjusting so that producers of all grades may receive a fair compensation. But this assumption is hardly probable for the bulk of the wheat grades, in most years, No. 1 and No. 2 Northern, and the millers handling these grades are, apparently, doing a profitable business.

It would seem, therefore, that we would be justified in concluding that the present system of grading wheat is not equitable, and that the difference between No. 1 and No. 4 and Rejected is too large a margin, and the farmer whose wheat grades low does not receive a fair compensation in proportion to its true value for milling purposes.

We may present our data in a more concrete form by following two farmers, each with a load of wheat, and see the final outcome for each individual case.

SOME MILLING DATA

Let us take two typical cases that are cited in Special Bulletin No. 14, Volume 3 Food Department, of wheat that graded No. 1 Northern and another sample grading Rejected. Let us assume that two farmers, John Smith and Ole Anderson, came to town, each with a load of wheat, 6,000 pounds. John Smith's wheat graded No. 1 Northern, dockage 2.51%. Ole Anderson's wheat graded Rejected with 13.96% of screenings. Now let us see what each of these men would have received at the prices as then prevailing.

John Smith with 2.51% of screenings, would have a dockage of 155.6 pounds, or, the total amount $(6000 - 155.6) = 5844.4$ pounds of wheat, the actual weight of which was 61.12 pounds per bushel; or, as sold at 60 lbs. per bushel $(5844.4 \div 60) = 97.5$ bushels. This wheat was quoted at \$1.17 per bushel, or $(97.5 \times \$1.17) = \114.07 , as the amount received by John Smith for his load of wheat.

Ole Anderson, on the other hand, for his 6,000 pounds of Rejected wheat with 13.96% dockage, would get $(6000 \times 13.96\%)$ 837.6 pounds dockage, or, $(6000 - 837.6) = 5162.4$ pounds of wheat. This $(5162.4 \div 60)$ would be equivalent to 86.0 bushels of wheat, and at the price quoted for Rejected at the time was \$1.048, or, $(86.0 \times \$1.048)$ would give \$90.128, as the amount received by Ole Anderson for his 6,000 pounds of wheat taken to the market.

Let us see what would be produced from the wheat for each of these parties. John Smith's 6,000 pounds of wheat, grading No. 1 Northern, would produce as follows:

	Pounds
Screenings	155.6
Flour, Straight	3935.03
Wheat Bran	953.18
Shorts	875.36
Loss in milling	61.36

The amount received for these products at the prices then current would have been:

Flour $(3935.03 \times \$2.88)$	\$113.329
Bran $(953.18 \times \$1.00)$	9.532
Shorts $(875.36 \times \$1.25)$	10.942
Screenings $(155.6 \times \$0.60)$	0.933
Total receipts	<u>\$134.736</u>

The cost, as we have already indicated, for this wheat was \$114.07. This gives a gain of 18% above the original cost.

On the other hand, Ole Anderson's 6,000 pounds of wheat would produce:

	Pounds
Screenings	837.00
Flour, Straight	3287.4
Wheat Bran	962.27
Shorts	845.16
Loss in milling	17.55

The amount received for the sale of this would be:

Flour (3287.4 x \$2.88)	\$94.677
Bran (962.27 x \$1.00)	9.622
Shorts (845.16 x \$1.25)	10.564
Screenings (837.60 x \$0.60)	5.025
Total receipts	\$119.888

The total cost for this wheat was \$90.13. The gain here would have been 33 per cent above the cost of the original wheat. If it costs 18 per cent to mill and market a given amount of Grade No. 1 wheat, is 33 per cent for milling and marketing a like quantity of Rejected grade out of proportion?

BY-PRODUCTS

If North Dakota produces for the market 100,000,000 bushels of wheat in a year, the amount of products, according to the average results as shown in the preceding pages, for the several by-products,—screenings, bran and shorts, expressed in pounds and tons, would be as indicated below:

TABLE XXI. BY-PRODUCTS

	Pounds	Tons
Screenings	239,400,000	119.700
Bran	762,600,000	381.300
Shorts	909,000,000	454.560

This valuable feed for live-stock, for the dairy, and for hogs, should be retained in the state, and the fertility now being removed from the soil and shipped out of the state should be returned again to the soil.

ANALYSIS OF BY-PRODUCTS

A partial analysis of these several by-products,—screenings, bran and shorts, shows:

TABLE XXII ANALYSIS OF BY-PRODUCTS

	Screenings	Bran	Shorts
Nitrogen, Percent	1.95	2.49	2.46
Ash, Percent	3.73	5.07	3.59

ANALYSIS OF ASH

Phosphoric acid, P_2O_5	28.69	58.78	59.33
Potash, K_2O	15.82	12.03	14.21
Lime, CaO	4.02	1.68	2.51

Using this data the amount of fertility removed by a 100,000,000 bushel marketable crop, in pounds, would amount to:

TABLE XXIII. FERTILITY REMOVED IN BY-PRODUCTS

	Nitrogen	Phosphoric Acid P_2O_5	Potash K_2O	Lime CaO
Screenings	4,668,300	2,561,580	1,412,460	359,100
Bran	18,988,740	22,725,480	4,651,860	610,080
Shorts	22,361,400	19,361,700	4,635,900	818,100
Total	46,018,440	44,648,760	10,700,220	1,787,280

All this fertilizing material should be retained in the state and returned to the land. The state can only become great agriculturally and continue its development by promoting such a system as will enable the return of at least a considerable share of this fertility and the marketing of products in the form of beef, pork, mutton, butter, flour and the finished bread products. To insure this end means the development of the manufacturing agricultural industries to the fullest possible utilization of all these products on the farm, in the dairy, in the mill and in the bakeries, and these industries should be encouraged, fostered and developed by the state through every reasonable means so as to insure continued prosperity to all our people and to future generations.

135

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Sheep Feeding Trials at Williston Substation

By W. H. Peters and Chas. H. Ruzicka

Bulletin No. 115

Agricultural College, North Dakota
FEB. 1916

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SHEEP FEEDING TRIALS AT WILLISTON SUBSTATION

By W. H. Peters and Chas. H. Ruzicka

OBJECT OF TRIALS

Progressive farmers in North Dakota have for some years recognized the growing necessity of raising some form of live stock to convert into cash what might be termed the by-products of the grain farm. Some farmers have begun to grow beef cattle, some are keeping dairy cattle, some are raising hogs, and a few have begun to grow or feed sheep as a means of utilizing these feeds. Each fall a vast amount of feed goes to waste on stubble fields especially through lack of efficiency in gathering the grain from the shock when threshing. There is always some spilled grain, weed seeds and chaff about the straw piles which heretofore has been wasted. For gleaning stubble fields, cleaning up around straw piles and converting screenings and refuse grain into cash the sheep is the animal par excellence. This fact has been thoroughly established through previous practice, though for various reasons the outcome has not always been profitable.



Fig. 1. Group of alfalfa and grain fed lambs just before going to market.

Believing that if intelligently and carefully managed it would be profitable to stubble graze and fatten western range grown sheep and lambs in North Dakota in the fall and winter months, a series of sheep feeding trials was begun at the Williston Sub-Station in the fall of 1914. These trials will continue for several years so that an average result of one year with another may be secured. The object of this work is to try out several different methods of feeding, especially to determine with what profit sheep may be fattened in this state.

The Williston Sub-Station was selected for this work because with the irrigation project located there and Missouri River bottom lands, which in the near future are bound to produce an abundance of corn and alfalfa each year, some type of live stock feeding must

be practiced in order that these crops may be marketed to the best advantage. There is no reason, however, why sheep feeding should not prove just as profitable in any other part of the state as at Williston.

THE 1914 TRIAL FEED IN TRANSIT PRIVILEGE LOWERS FREIGHT

In the fall of 1914 a carload of 270 head of range grown Hampshire grade lambs were purchased at Oswego, Montana and arrived at Williston on October seventeenth. They were shipped under the feed in transit privilege which allows shipping stock of any kind from western points to points intermediary between the place of origin and



Fig. 2. Cut showing type of feed racks and straw shed used for feeding and shelter for lambs of the 1914 trial.

either St. Paul or Chicago, where they may be fed for a period of not to exceed six months, and may be reloaded and sent on to market. The total freight charge then is the through rate from point of origin to market plus a five dollar switching charge per car at the point where the car is unloaded. This privilege is executed by the full local rate being charged when the sheep are shipped in and then the difference between the through rate from point of origin to market and the two local rates added together is deducted from the local rate from feeding point to market. The five dollar switching charge being added at this time. The average amount of freight saved by this privilege is about ten cents per hundred pounds.

FEEDS USED AND METHOD OF FEEDING

An abundant supply of medium quality of alfalfa hay on hand at the Sub-station farm had determined that for 1914 the feeding should be largely on alfalfa. The statement has occasionally been seen in print that animals of various kinds can be successfully fattened on alfalfa as the sole feed. In order to give this method of feeding a trial, fifty average lambs were cut out of the bunch and fed in a yard by themselves receiving no feed except good alfalfa hay, all they would eat. They, of course, had salt before them at all times and were regularly watered twice a day. For shelter these lambs had a frame shed that was kept well bedded,



Fig. 3. Group of "Finished" alfalfa and grain fed lambs.

The remainder of the load consisting of 220 head were fed in one group in another yard. They received all the alfalfa hay they would clean up good and a light grain ration composed of elevator screenings for about one-third of the time they were on feed, and corn and barley the remaining two-thirds of the time. The original intention was to feed, throughout the period until the lambs were ready for market, on alfalfa and screenings. At the end of thirty-five day's feeding the supply of screenings available was exhausted. Because of inability to secure more of them at anything like a reasonable price, and because gains from them had not been satisfactory the grain feed was changed to corn and barley. The corn was grown on the Sub-station farm and was a little soft but ripe enough to keep well. It was run through a grain grinder cob and all before feeding. The sheep ate the cob just as readily as the corn. As long as the corn lasted it was mixed with the barley half and half and fed in that way. The barley was fed whole. The corn was fed along

with the barley for a period of six weeks after which barley alone was fed as the grain until the sheep were marketed.

All of the feeding was done in racks that were built so as to hold enough hay for a couple of days. The grain was fed in these same racks. During the early part of the feeding period while screenings were being used the grain was fed at the rate of about one-half pound per lamb per day. This amount was gradually increased until toward the close of the period when barley alone was being fed, each lamb was eating about one and one-half pounds of barley per day.



Fig. 4. Cut showing condition of lambs fed alfalfa hay alone.
Photo taken toward the close of the trial.

STRAW SHED FOR SHELTER

For shelter for this group of lambs a straw shed was built by putting in ten-foot posts ten feet apart and nailing 2-in. by 6-in. stringers across the tops of these to brace them and support the woven wire which in turn supported the straw for the roof. An opening 8 feet wide was left in one end of the shed to serve as a door. Outside of this framework another line of six foot posts was set and woven wire tacked on to them to hold the straw in place. This outside row of posts was three feet away from the inside ten foot posts thus making a trench three feet wide to be filled with straw to form the sides of the shed. Woven wire was likewise stretched lengthwise of the shed over the 2-in by 6-in. stringers to support the straw for the roof. Straw was piled over the roof to a depth of two feet, just enough to keep the snow from sifting through. The total cost of the material in this shed was:

12-10' posts at 25 cents each	\$ 3.00
12- 6' posts at 15 cents each	1.80
6 pieces 2"x6"x16' lumber	3.00
40 rods 4' woven wire at 30 cents	12.00
Fence staples	.20
Total	\$ 20.00

This frame work will be good for five years and the expense of the shed is, therefore, placed on this basis in proportioning the shelter cost giving the proportionate cost of the shed for the year as:

Depreciation	\$ 4.00
Interest on \$20.00 for one year at 6%	1.20
	\$ 5.20



Fig. 5. Carcass views of best grain fed lambs.

An interesting fact in connection with the shelter is that the lambs preferred to sleep out of doors about the feed racks at all times except when the wind was blowing hard. They did not go into the shed to sleep for more than five or six nights during the entire time they were on feed, yet for these few nights when shelter was badly needed it paid well to have the shed for them.

CONSTRUCTION OF FEED RACKS

The feed racks used in feeding these lambs were constructed by using 2-in. x 4-in. material for the frame work and bracing and 1-in. x 12-in. material for the sides and bottoms of the racks. The accompanying cut (Fig. 2) showing a view of the racks gives an idea of how they were constructed. To feed the 270 lambs required nine sections of double racks each 16 feet long. The total width of the grain troughs at the bottom was 12-in. each or 24-in. for the double racks. The total height 4 feet and width of racks at the top 3 feet. The total cost of the material used in these racks and in the water troughs was \$38.73. It can reasonably be estimated that these racks would last five years and the proportionate cost therefore to be charged against the 1914 trial is:

Depreciation	\$ 7.74
Interest on \$38.73 at 6%	2.32
	\$10.06



Fig. 6. Carcass views of poorest grain fed lambs.

FINANCIAL STATEMENT

As the principal object in conducting this feeding trial was to determine with what profit the sheep could be fed, a very careful

record was kept of all cost and expense items. The following table gives the result from the financial standpoint.

COSTS

Feed Cost:

45.7 tons of alfalfa hay at \$6.00 per ton	\$274.20
5070 lbs. elevator screenings at \$12.00 per ton	30.42
80 bu. low grade feed barley at 33½c per bu.	26.80
144.5 bu. feed barley at 48c per bu.	69.36
80 bu. ear corn at 50c per bu.	40.00
1500 lbs. mangles and beets	2.00
1 bbl. salt	2.00

Miscellaneous Expense Items:

Proportionate cost of material in feed, racks and water troughs	10.06
Proportionate cost of material in shed	5.20
Expenses trip Williston to Oswego to purchase lambs..	5.00
Expenses of attendant accompanying car to market.....	7.25
Freight on car of lambs Oswego to Williston	38.95

Cost of Lambs:

270 lambs wt. 19755 lbs. at 5½c	1086.53
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\$1597.77

RECEIPTS

Received for 262 lambs sold on the St. Paul Market, all freight, commission, yardage and feed charges deducted	\$ 1748.47
	<u>1597.77</u>

Labor Income	150.70
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The above statement reduces the profit or return from the enterprise to the labor income basis. The \$150.70 does not look like a large labor return but when it is learned that a careful record kept by hours of the amount of time required to look after the entire enterprise totaled 35 days of ten hours each it will be seen that a very fair wage of \$4.30 per day for the time utilized was earned. The total of 35 days includes the time required in making the trip to Oswego to purchase the lambs, time utilized in making the racks and shed, time utilized in feeding the sheep and that utilized in accompanying them to market.

LOSS OF LAMBS DURING TRIAL

The labor income or profit was considerably lowered in this trial through the loss of three lambs while on feed and the further loss of five lambs through piling up in the car while enroute to market. However, it is not the purpose of the above statement to make any excuse for the return secured from the trial or for the loss of the several lambs. The loss of lambs is a feature which is likely to happen to any farmer and some loss through injury or sickness must always be anticipated in any live stock project.

INCREASE OF FARM INCOME THROUGH THE FEEDING TRIAL

When considered from the standpoint of how much the income from the farm was increased through the feeding of the sheep and thus making a home market for feeds that otherwise would have been difficult to sell we get the following figures:

Received for 45.7 tons alfalfa hay	\$ 274.20
Received for 80 bu. low grade barley	26.80
Received for 80 bu. ear corn	40.00
Received for 1500 lbs. mangels and beets	2.00
Labor income	150.70
Total	\$ 493.70

The \$493.70 represents the amount by which the bank account was increased through the feeding of the sheep.



Fig. 7. Carcass views of best lambs fed alfalfa hay only.

VALUE OF MANURE

In North Dakota it has not yet been learned that a money value may correctly be placed on manure. However, through the feeding of this carload of sheep were produced sixty loads of the finest kind of manure which when it comes to invoicing the farm and equipment should be valued at least at \$1.00 per load or \$60.00.

This would raise the return from the feeding enterprise from \$493.70 to \$553.70.

ALFALFA VS. ALFALFA AND GRAIN

For the purpose of showing the difference between alfalfa and grain as a ration for fattening lambs and alfalfa feeding alone the following table is presented. Lot one was fed alfalfa and grain, and lot two alfalfa only.

	Lot 1.	Lot 2.
Original weight per head	73.16 lbs.	73.15 lbs.
Original cost per 100 lbs.	\$ 5.50	\$ 5.50
Original cost per head	\$ 4.02	\$ 4.02
Shrink per head during shipment to the Substation ...	8.25 lbs.	5.88 lbs.
Weight per head at beginning of trial	64.91 lbs.	67.28 lbs.
Number of days on feed	103	103
Total amount of hay consumed per head	314 lbs.	388.6 lbs.
Average amount of hay consumed per head per day....	3.05 lbs.	3.77 lbs.
Total value of hay consumed per head	\$.942	\$ 1.17
Total amount of grain consumed per head	96.82 lbs.	.....
Average amount of grain consumed per head per day	.94 lbs.	.....
Total value of grain per head	\$.76	.....
Weight per head at close of period	95.82 lbs.	83.92 lbs.
Total gain per head	30.91 lbs.	16.64 lbs.
Average gain per head per day	.3 lbs.	.161 lbs.
Average weight per head on market	87.8 lbs.	77.62 lbs.
Shrink per head enroute to market	8.02 lbs.	6.3 lbs.
Average selling price per 100 lbs.	\$ 8.40	\$ 8.25
Average selling price per head	\$ 7.38	\$ 6.40
Feed cost per 100 lbs. gain	\$ 5.178	\$ 7.031
Feed cost per head for the period	\$ 1.70	\$ 1.17
Margin per head over purchase price plus feed cost....	\$ 1.76	\$ 1.21
Margin per 100 lbs. in selling price over purchase price	\$ 2.90	\$ 2.75

RESULTS OF 1914 TRIAL

1. From a financial standpoint the 1914 trial was successful and the profit a fair one.
2. The feeding of grain in addition to alfalfa hay practically doubled the gains for the entire period.
3. The feeding of grain with the alfalfa increased the margin between the purchase price plus feed cost and the selling price from \$1.21 for the alfalfa lambs to \$1.76 for the alfalfa and grain lambs or a difference of \$.55 per head in favor of the grain feeding.
4. The dressing percentage on the alfalfa and grain fed lambs was 53.1 per cent and on the alfalfa fed 50.3 per cent.
5. The grain fed lambs topped the market selling at the high point for the week.
6. Due to the good form, mutton type and quality of the alfalfa fed lambs they were discounted but 15 cents per 100 pounds when sold even though they were lacking in condition.

THE 1915 TRIAL

During the fall of 1915 a second trial was conducted, though the feeding was very different than in 1914. Plans for the 1915 trial were made in the spring of that year. It was decided then to try

fall feeding instead of winter feeding as in 1914. The idea being that the sheep could be made ready for market on cheaper feed, in less time and at a lower labor cost. Accordingly a field of 6½ acres of corn was planted to be pastured off in the fall, and the stubble fields on the station farm were grazed until snow made them no longer serviceable, following which alfalfa hay and barley were fed for a period of six weeks or just long enough to make the lambs fat enough to sell as choice butcher lambs.

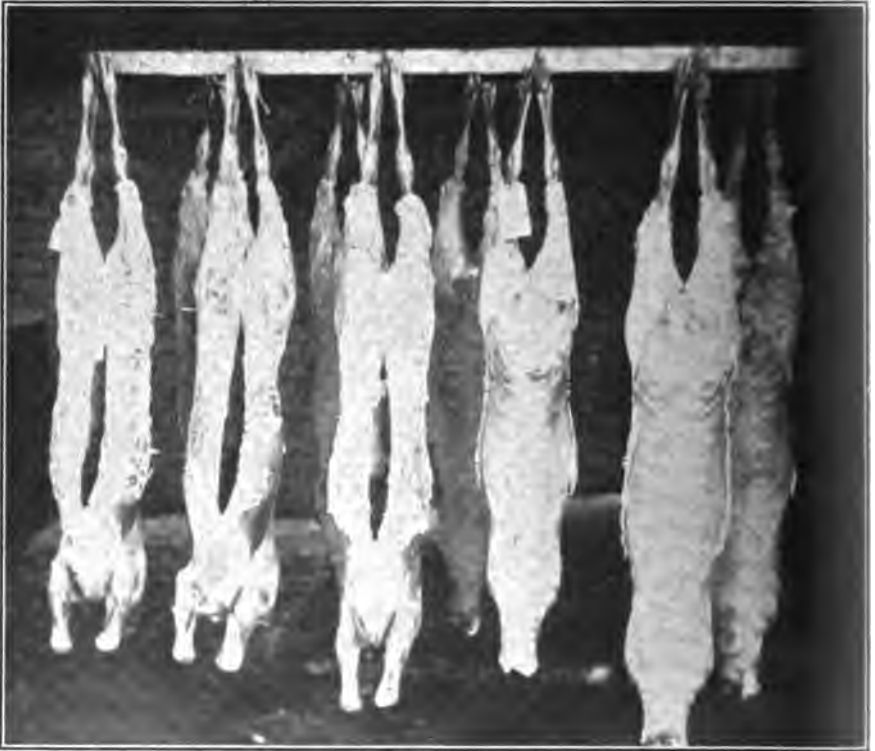


Fig. 8. Carcass views of poorest lambs fed alfalfa hay only.

This year the lambs were purchased at Chinook, Montana for delivery during the latter half of September. They arrived at Williston on September 25th. The number purchased was 210 head. After being rested, fed and watered they were weighed up on the morning of September 26th and the 210 head averaged 60.1 pounds. They were rather plain bred lambs and rather thin and common in appearance. They were all out of range bred Merino ewes and about half of them were sired by high grade Rambouillet rams and half of them by high grade Hampshire rams. They were purchased by the head the price being \$3.37½ which figures out to \$5.615 per 100 pounds.

Owing to the fact that the threshing was not finished and the stubble field not available when they arrived they were turned into the corn patch first and kept there as long as the corn field provided feed.

The summer season was rather dry at Williston and the corn had made a very light growth and had formed practically no ears. Following the last cultivation rape had been seeded in between the rows of corn but the weather was so dry that the rape did not even come up and no feed at all was secured from it.

The lambs ate the corn very readily and cleaned the field of weeds and every bit of green growth there was on it, leaving the field in the finest kind of shape to be disked next spring and seeded to wheat. The six and one-half acres of corn provided feed for the 210 head for 18 days only. They were left in the corn field night and



Fig. 9. Cross section of carcasses of grain fed lambs.

day and water hauled to them. When the corn field no longer provided sufficient feed the lambs were given the run of the stubble fields. While pasturing stubble they were corralled in the corn field at night and were given a light feed of alfalfa hay and a little grain. They, of course, ate the grain readily but ate very little alfalfa hay until the snow came and stopped the grazing and made hay feeding altogether necessary. This was on November 7th and from that time until they were shipped to market on December 9th they were fed a good quality of alfalfa hay, all they would eat and clean up well. Heavy grain feeding was begun on November 7th also. Barley was used as the principle grain feed but some refuse grain and a little soft corn was also fed. The grain was all fed whole and an effort was made to coax them to eat all they would. While

getting all the good hay they cared to eat they would not consume more than an average of $1\frac{3}{4}$ pounds of barley per head per day, and that only for a short time toward the end of the period.

During the summer of 1915 the framework for the straw shed built in 1914 was taken down and the posts and wire used in constructing a fence on the Sub-station farm. Inasmuch as it was planned to market early this year no shelter was provided, the lambs sleeping out of doors all of the time until shipped to market on December 9th. At intervals when necessary to keep the yard dry a load of straw was hauled in and spread around for them to sleep on. This aided materially in conserving the manure and putting it in shape to be handled with a fork and manure spreader. Only one lamb was lost during this entire feeding trial.

The following financial statement gives an idea of the success of the 1915 trial.



Fig. 10. Cross sections of carcasses of lambs fed alfalfa hay alone.

FINANCIAL STATEMENT

Feed Cost:

21590 lbs. alfalfa hay at \$10.00 per ton	\$ 107.95
36 bu. soft corn at 30c per bu.	10.80
2120 lbs. refuse grain at \$14.00 per ton	14.85
7218 lbs. barley at 45c per bu.	67.68
3432 lbs. barley at 48c per bu.	34.32
Cost of growing 6 acres of corn	30.50
30 lbs. rape seed	4.90
80 lbs. seed corn	4.80
$\frac{1}{2}$ -bbl. salt	1.00

Miscellaneous Items:

Depreciation and interest on feed and water troughs	\$ 10.06
Expenses trip Williston to Chinook to purchase lambs	8.00
Expenses trip of attendant accompanying lambs to market	7.45
Freight on lambs Chinook to Williston	43.38
Cost of 210 lambs at $3.37\frac{1}{2}$ per head	708.75

\$1054.44

Received from sale of 209 lambs all commission, freight and yardage charges deducted	\$1248.92
	<u>\$1054.44</u>

Labor income	\$ 194.48
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The labor income of \$194.48 is considerably above that of the 1914 trial. Furthermore the total amount of labor utilized in conducting the 1915 trial totaled 250 hours or 25 ten hour days the labor return is therefore equivalent to \$7.78 per ten hour day.

The amount by which the bank account was increased through the feeding of the lambs and thus making a market for the feeds used was \$358.58. This is considerably lower than the corresponding figure for 1914, due to the fact that a smaller number of lambs were fed and a higher percentage of the grain used had to be purchased.

The amount of manure produced can reasonably be valued at \$40.00 thus increasing the invoice valuation of the feeding project to \$398.58.

The following table showing the amount of feed consumed per head for the period, amounts per day, etc., will be of interest to the student in sheep feeding and is therefore presented.

Original Cost of 210 lambs	\$ 708.75
Original weight of 210 lambs	12621 lbs.
Original weight per head	60.1 lbs.
Original cost per 100 lbs.	\$ 5.615
Original cost per head	\$ 3.375
Weight per head at beginning of trial	60.1 lbs.
Total value of hay consumed	\$ 107.95
Number of days on feed	75
Total amount of hay consumed	21590 lbs.
Average amount of hay consumed, per head	102.80lbs.
Cost of hay consumed, per head	\$.514
Total amount of grain consumed	15290 lbs.
Total value of grain consumed	\$ 127.65
Total amount of grain consumed, per head	72.8 lbs.
Average value of grain consumed, per head	\$.60
Cost of corn field pastured by sheep	\$ 40.20
Cost of corn field, per head	\$ 0.19
Total weight at close of period	17096 lbs.
Weight per head at close of period	81.8 lbs.
Total gain per head	21.7 lbs.
Average gain per head per day	.29lbs.
Total selling weight	15716 lbs.
Selling weight, per head	75.2 lbs.
Shrink enroute to market	6.6 lbs.
Feed cost per head for period	\$ 1.318
Average selling price per 100 lbs.	\$ 8.53
Average selling price per head	\$ 6.415
Total margin per 100 lbs.	\$ 2.915
Margin per head over purchase price plus feed cost	\$ 1.722

COMPARISON OF GAINS MADE BY SMALL VERSUS LARGE LAMBS.

In the fall of the year when buying lambs to feed, it is often a difficult problem for the feeder to decide whether he had best feed yearling wethers, old ewes or large or small lambs and whether or not it will pay to feed a medium quality of sheep or to buy the best that can be found.

To decide this point a very thorough knowledge of the condition of the sheep market and ability upon the part of the buyer to judge the market value of various types of sheep is required. To get a little information on this problem when the lambs were put on feed in 1915, fifteen of the smallest ones and fifteen of the largest ones were weighed individually and marked, then at the close of the trial the same lambs were weighed again with the following result:



Fig. 11. Group of lambs used in the 1915 trial.

Average weight of 15 small lambs at beginning of the trial	48.8 lbs.
Average weight of 15 small lambs at close of the trial	68.9 lbs.
Average gain per head	20.1 lbs.
Percentage gain	41.19%
Average weight of 15 large lambs at beginning of trial	75.1 lbs.
Average weight of 15 large lambs at close of the trial	98.4 lbs.
Average gain per head	23.3 lbs.
Percentage gain	31.02%

The large lambs made the greater actual gain by 3.2 pounds per head but when placed on the basis of percentage of increase in weight the small ones made the greatest percentage increase by 10.17 per cent.

However, when placed on the market the 15 large lambs sold at \$8.65 per 100 pounds and the 15 small ones at \$8.00. This fact would indicate that the small lambs if one were buying a carload of them would have to be bought at a lower price per pound than the large ones if as much profit were to be made in feeding them. In this trial it would have been necessary to purchase them at least 60 to 75 cents per 100 pounds cheaper.

RESULTS OF 1915 TRIAL

1. From a financial standpoint the 1915 trial was successful and the labor income quite satisfactory.

2. Grazing on corn and stubble proved successful and aided considerably in keeping down the cost of gain for the entire feeding period.

3. Thirty-five days of hay and grain feeding at the close of the stubble season was sufficient to put the lambs on the market as choice butcher lambs in good killing condition.

CONCLUSIONS

It is the intention to continue sheep feeding trials similar to those already conducted for several years more in order to secure more conclusive data on the possible profits from such feeding enterprises. Observation on the stubble grazing done by farmers through the state during the past several years together with the results of the above two trials, however, bring out some facts that may be relied upon in feeding range sheep.

1. The margin between cost price and selling price per 100 pounds is the chief factor in determining the amount of profit that will be made. In other words before buying sheep to feed the market must be studied and the sheep must be carefully bought. A margin of $1\frac{1}{2}$ cents per pound in selling price over purchase price is ordinarily necessary to insure a profit.



Fig. 12. Group of small sized lambs used in 1915 trial, average weight at beginning 48.8 lbs., average weight at close 68.9 lbs.

2. It is not advisable to depend on stubble grazing alone to fatten sheep unless there is a considerable amount of waste grain and considerable green growth on the fields. Also to make fattening on stubble alone a safe proposition the sheep must be secured by the middle of September otherwise an early snow may cut short the feeding period to such an extent that the sheep will have to be offered on the market again as feeders and a low price per pound accepted for them.

3. Stubble grazing can be made highly profitable if some suitable additional feed is provided so that regardless of weather conditions the sheep may be put in good killing condition before selling. These additional feeds can best be provided by growing some alfalfa and corn on the farm to be used for that purpose.

4. It is not advisable to depend on alfalfa hay alone to fatten sheep.

5. The chances for profit are naturally greatest with a group of good sized, healthy, growthy appearing lambs provided they do not cost too much in the beginning. Sometimes a group of second rate sheep will make a greater profit because of a considerably lower cost price.

6. During the past several years the tidy western range grown lamb of fair mutton type and good quality has outsold the heavier mature mutton lambs. The packers give as the reason for this the superior quality of meat and higher dressing percentage of the range lamb.



Fig. 13. Group of large sized lambs used in 1915 trial, average weight at beginning 75.1 lbs., average weight at close 98.4 lbs.

7. A fifty-six to sixty-four pound lamb is a good weight to begin with for a sixty to one hundred day feeding period, as a lamb weighing from seventy-five to ninety pounds in good killing condition when marketed is most certain to find a welcome reception and top price on the market.

8. If screenings are used as the grain ration they should be carefully examined before buying and the price based on the quality of the screenings. Screenings that contain a high percentage of wild oats or wheat are highest in feeding value while screenings composed principally of small weed seeds have little feeding value.

9. All that is necessary as a shelter for feeding sheep during the fall months is protection from the wind and a dry place to sleep. For winter the feeding may be done out of doors and a straw shed constructed very satisfactorily and cheaply for shelter.

10. Sheep will eat whole barley satisfactorily and do well on it.

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North Dakota

Agricultural Experiment Station

The Influence of Energy Material Upon the Relation of Soil
Microorganisms to Soluble Plant Food

By C. J. T. Doryland

Bulletin No. 116

Agricultural College, North Dakota
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THE INFLUENCES OF ENERGY MATERIAL UPON THE RELATION OF SOIL MICROORGANISMS TO SOLUBLE PLANT FOOD

By C. J. T. Doryland

Experiments with synthetic solutions containing ammonia as the only source of nitrogen have shown that a number of the most common soil organisms (bacteria, actinomyceetes and molds) could assimilate ammonia nitrogen. To a less extent the same thing is true with nitrate nitrogen. The assimilation of either the ammonia or nitrate nitrogen takes place only when suitable energy material is present. The energy materials thus far used have been nitrogen free organic compounds, such as sodium or potassium salts of organic acids or soluble carbohydrates.

Among the ammonia consuming bacteria may be found some of the most vigorous ammonifiers. The knowledge that some bacteria, yeast and molds may consume ammonia or nitrate nitrogen is not new, but the significance of ammonia consuming ammonifiers seems to have been overlooked. Hitherto, the consumption of ammonia or nitrate nitrogen by soil microorganisms has been regarded as due to certain "detrimental" bacteria, yeast, molds, etc., which were favored by certain vaguely defined "soil conditions". When however, one considers the possibility of ammonia or nitrate assimilation as a normal function of certain "beneficial" bacteria, yeast and molds, it is obvious that the conditions under which ammonifying organisms liberate ammonia and the conditions under which they assimilate ammonia vitally affects the available nitrogenous plant food constituents of the soil. It would appear as though the presence of suitable energy material might cause the ammonifying organisms to consume ammonia instead of providing it for the nitrifying organisms or for direct plant* growth. To this extent ammonifying bacteria in the presence of excess available energy material lose their ammonifying efficiency and become competitors for the available nitrogen of the soil. Likewise, the presence of excess available energy material may cause these beneficial organisms to assimilate some of the other available plant food constituents. The great mass of organic matter added to the soil annually contains a low percent of nitrogen and a high percent of energy yielding material. What effect has this excess energy material upon the physiological activities of the soil organisms?

STATEMENT OF THE PROBLEM

Six common ammonifiers have been tested for their ability to consume ammonia in the presence of dextrose as a source of energy. The organisms used were: *B. mycoides*, *B. subtilis*, *B. megatherium*, *B. proteus*, *B. vulgatus* and *Sarcina lutea*. These cultures were obtained from the American Museum of Natural History through the courtesy

* Throughout this article, plants refers to the higher plants; micro organisms are so designated or referred to as bacteria, yeast, molds, etc.

of Dr. C. E. A. Winslow and were numbered respectively as follows: 249, 106, 257, 142, 528, and 208.

Through a series of experiments the following features have been investigated:

The ability of these organisms to grow and produce ammonia from casein both in the presence and absence of dextrose;

The effect of increasing quantities of dextrose upon the number of bacteria and the ammonia production in a casein solution;

The competitive action between the ammonifying bacteria and maize seedlings when grown in the presence of dextrose;

And the effect of dextrose upon the growth of oats in a series of pots containing quartz sand to which had been added increasing quantities of ammonium sulphate, potassium nitrate, casein or manure.

These experiments have been supplemented by tests of the ammonia and nitrate consuming power of certain soils; and

The effect of dextrose and straw upon the ammonia and nitrate consuming power of soils.

PREVIOUS WORK

Numerous investigators have noted the fact that bacteria, yeast and molds may assimilate ammonia or nitrate nitrogen. Others have noted the fact that the addition of a soluble carbohydrate or salts of organic acids disturbs the metabolism of soil nitrogen. Still others have observed the assimilation of available phosphates.

THE ASSIMILATION OF AMMONIA AND OF NITRATE NITROGEN

Löhnis (1)* gives an excellent summary of the French and German literature from the first observations by Dujardin (1841) to the contributions by Bierema (1909).

In addition to the references noted by Löhnis, the following have been secured mostly from the Experiment Station Record and the Centralblatt für Bakteriologie Zweite Abteilung.

Lemmerman, Fischer and Husek (2) tested the effect of CaCO_3 , BaCO_3 , MgCO_3 and $\text{Fe}_2(\text{OH})_6$ upon the transformation of $(\text{NH}_4)_2\text{SO}_4$ and NaNO_3 to bacterial protein. BaCO_3 increased the transformation in the case of $(\text{NH}_4)_2\text{SO}_4$, but decreased it with NaNO_3 . CaCO_3 slightly increased the transformation in the case of $(\text{NH}_4)_2\text{SO}_4$ and in a less degree with NaNO_3 . The influence of MgCO_3 was doubtful. $\text{Fe}_2(\text{OH})_6$ reduced the transformations in every instance. Ammonia was transformed to a greater extent than nitrate. The authors, therefore, conclude that the lower efficiency of ammonium sulphate as a fertilizer may be due to the greater use of the ammonia by microorganisms.

Lutz (3), studying the comparative assimilability by plants, of ammoniacal salts, amines, amides, nitrates, states that in general nitrogenous compounds are assimilable in proportion to the complexity of

* See bibliography.

their molecules. *Aspergillus* and *Pennicillium* were used as test plants.

In an article entitled: "Ammonia and Nitrate as a Nitrogen Source for Molds", Ritter (4) shows that ammonia and nitrate nitrogen may be used as a source of nitrogen by *Mucor*, *Rhizopus*, *Aspergillus*, *Cladosporium*, *Botrytis* and *Thamnidium*.

The action of certain microorganisms of the soil on ammonium sulphate and sodium nitrate, as studied by A. Stutzer and W. Rothe (5) show that there is a definite conversion of ammonia and nitrate nitrogen to albumid nitrogen by various soil organisms, both in the presence and absence of CaCO_3 . Ammonia was more rapidly transformed than nitrate, except in case of *P. glaucum*. Calcium did not increase the rate of conversion.

Stoklasa's (6) investigation continued from previous work* in which the author attempts to show; (1) The source of carbon most favorable to the denitrifying organisms in the medium; (2) The nature of the chemical changes which take place; and (3) The importance of denitrification in relation to soil processes. He concludes there are present in soils and manures two principal groups of bacteria which cause denitrification. The first group consists of *B. hartlebii*, *B. fluorescens*, liq. *B. pyocyaneum*, *B. stutzeri*, *B. centropunktatum*, *B. filefaciens*, *B. denitrificans*, *B. nitrovorum*, etc. These organisms reduce NO_3 to N. The second group consists of *B. megatherium*, *B. mycoides*, *B. subtilis*, *B. messentericus vulgatus*, *B. ramosus*, *B. typhi abdominalis*, *B. coli communis*, *B. proteus vulgatus*, *B. Zenkeri*, *B. radiceicola*, *Clostridium gelatinosum* etc. These organisms, as a rule, simply reduce NO_3 to NH_3 without the formation of elementary N. They also appear to have the power to assimilate the NH_3 formed. A still later contribution (7) on this subject confirms the above, and states that *B. hartlebii* consumed 33.6% of the nitrate nitrogen in solutions containing arabinose.

Reduction of nitrates in the presence of barnyard manure was the subject of investigations by J. P. Street (8) at the New Jersey Station. In one series he ran sodium nitrate alone at the rate of 83 pounds per ton of manure, and nitrate, acid phosphate, kainit, gypsum, iron sulphate and K_2SO_4 , each at the rate of 26 pounds per ton of manure, glucose, wheat straw or pine shavings at the rate of 133 pounds per ton of manure.

In a second series $(\text{NH}_4)_2\text{SO}_4$ was substituted for the NaNO_3 . At the end of 33 days the nitrate had entirely disappeared from the manure where glucose, wheat straw or shavings had been added. There was a marked increase in the insoluble organic matter,—glucose giving an increase twice as great as straw or manure alone.

The loss of $(\text{NH}_4)_2\text{SO}_4$ varied from 13.1% to 33.8%. The gain in insoluble nitrogen was 34% where manure was used alone and 102.7% where manure was used with $(\text{NH}_4)_2\text{SO}_4$ and gypsum.

Experiments on ammonia and nitrate formation in soils were conducted by J. G. Lipman and P. E. Brown (9) at the New Jersey Station. They studied the effect of soluble and insoluble carbohy-

*Experiment Station Record 12, p. 27 and p. 614.

drates, such as dextrose, starch and filter paper, on ammonification and nitrification of nitrogenous materials in soils. Ammonin formation was depressed most by dextrose and showed a slight depression for starch and cellulose. Ammonia formation by *B. mycoides* was lessened in the presence of dextrose.

L. C. Coleman (10) investigating the influence of dextrose, sucrose, lactose, glycerin, peptone and urea, found the addition of small percents (.5%) of the non-nitrogenous substances in unsterilized soil seemed to favor nitrification. With almost pure cultures in sterile soils .02 to .05% of dextrose increased nitrification. These results are substantiated by the work of Karpinski and Niklewski, (11) who show that small amounts of organic matter such as furnished by soil extracts, humates, acetates and even peptone and sugars favor nitrification in mixed cultures.

Frankfurt and Duschekkin (12) studied the course of nitrification under the condition of field experiments using dung and green manures. They measured nitrification by the nitrate and ammonia in the soil. Increased nitrification was observed only in those fields which gave increased yields. Large quantities of strawy manure did not decrease the content of nitrate nitrogen. Green manures both legume and non-legume, lowered both NO_3 and NH_3 . They attributed this to a change of moisture.

Hutchinson and Marr (13) applied starch at the rate of one ton per acre. The yield of barley was decreased 25.7% on land that had not received manure or fertilizer since 1852, while on the land that had received a complete mineral fertilizer yearly since 1852, the decrease in yield of barley was 9.2%.

The addition of cane sugar at the same rate gave, in the first instance, a decrease of 39.3% and in the second a decrease of 22.9%. Examination showed a greatly increased number of bacteria and molds, and an increased evolution of CO_2 .

Vogel (14) experimenting with the assimilation of ammonia and nitrate nitrogen by microorganisms grown in solutions, points out the fact that an appreciable formation of albuminoid matter from NH_3 and NO_3 takes place. He believes, however, that no such transformations take place in natural soils. Where CaCO_3 was added to soils containing ammonium salts, there was considerably greater loss of nitrogen than could be accounted for by volatilization and suggests that the loss is due to denitrification.

A. Fousek (15), studying the streptothrix of the soil and the assimilation of nitrates, ammonia and amid nitrogen, points out that streptothrix chromogena and streptothrix alba are present in soils. According to this author, these organisms constituted 20 to 30% of the flora in loam soils, from 8 to 15% in clay soils and from 7 to 10% in sand. These organisms readily assimilate ammonia and nitrate nitrogen and decompose peptons, dried blood, bone meal and straw, splitting off large quantities of ammonia.

Lipman and associates (16) report the effect of dextrose, sucrose, lactose, maltose and mannit on ammonia recovered from dried blood. These authors suggest that the depression is due either to a depression of ammonification or to producing conditions favorable for organisms

which utilize ammonia. Ammonia recovered from rice flour and corn meal was about the same with dextrose as without it. With wheat flour, linseed meal, cowpea meal, soybean meal and cotton seed meal, the amount of ammonia was invariably less when dextrose was used.

The same authors report results of pot experiments with barley. In conjunction with other experiments, they tested the effect of dextrose and sucrose upon the ability of barley to recover the nitrogen of ammonia, nitrates and dried blood. The carbohydrate decreased the amount of nitrogen recovered by barley plants from all sources tested. In most cases, sucrose caused a greater depression than dextrose. With dried blood, tankage and with mixed fertilizers containing nitrogenous organic materials, it was shown that the percentage of organic nitrogen recovered by the barley was usually greater from samples having the highest percentages of organic nitrogen.

In a still earlier communication these authors, working on the availability of nitrogenous materials, as measured by ammonification, found that the addition of NaNO_3 stimulated the ammonification of inert materials like peat. On the other hand, dried blood did not stimulate ammonification in peat. On the contrary, it lost some of its own ammonifiability. Phosphates seemed to favor ammonification. Addition of manure infusions reduced the ammonification of dried blood.

McLean and Wilson (17), working with ammonifying fungi and using dried blood as ammonifiable material, find that the addition of acid phosphates caused an increase in the ammonifying power of 18 out of 26 pure cultures of soil fungi. When cotton seed meal was substituted for dried blood, only eight out of twenty five cultures showed increased ammonification in the presence of acid phosphate.

Hoffman (18) working on nitrogen fixation in soils, due to the application of carbohydrates, notes that the application of kainit and floats applied together with either sugar or starch caused a decrease in the amount of nitrogen fixed.

In a recent work of Fred and Hart (19) on the comparative effects of phosphates and sulphates on soil bacteria, they state that the addition of soluble phosphates causes an increase in the ammonification of a peptone solution by soil suspensions or pure cultures. There was likewise an immensely greater number of bacteria found where phosphates were added to the peptone solution. The greatest increase was caused by dibasic potassium phosphate. Ammonification increased with the increase in the numbers of bacteria. Likewise, the addition of soluble phosphates caused an increase in the liberation of CO_2 .

Addition of calcium sulphate and potassium sulphate caused an increased ammonification and carbon dioxide evolution, but to a less extent than the addition of acid phosphate. Calcium sulphate increased the number of bacteria. This agrees with the work of Lipman (20).

Koch (21) found that a soil kept for nine months under proper conditions of temperature and moisture showed an increase of 3.38 mgm. of nitrate nitrogen. During the next eleven months, however, there was an increase of only 1.39 mgm. of nitrates.

Fred (22) studying nitrification in certain types of Virginia soils found that when these soils were kept under protected conditions there was a greater accumulation of nitrate nitrogen than that recorded by Koch.

Brown (23), in his study of the effect of crop rotation, found that green manures did not always increase the number of bacteria in the soil. He suggests that probably the moisture factor or the incorporation of a large amount of organic matter might furnish an explanation for this fact. In every instance, continuous cropping to clover reduced the number of organisms. The reduction in numbers appearing very prominently even when no difference in moisture content was recorded.

Patterson and Scott (24) investigated the effect of various soil constituents upon nitrification and found that starch and sugar retarded nitrification.

Bredeman (25) found that the addition of organic matter, such as hay and sugar, produced a harmful effect upon the first year's crop but a beneficial effect upon the second year's crop.

Ehrenberg (26) states that straw retards a too rapid nitrification.

Enberding (27) found that straw or sugar cause an increase in the number of soil bacteria. Later the number of bacteria decreased to somewhat near normal. The ammonifying and nitrogen fixing groups of bacteria increased while the nitrifying group was retarded by this treatment.

Hill (28) investigated the effect of green manures on soil nitrates under greenhouse conditions and found that the total number of bacteria, rate of nitrate formation and rate of plant growth was much greater than in those soils receiving no green manure. On the other hand, pure cellulose in the form of Swedish filter paper caused a depression in the number of bacteria, in the rate of nitrate formation and plant growth. Paper was the cause of the yellow appearance of the plants which were grown in the pots receiving the addition of paper.

Gerlach and Vogel (41) isolated several pure cultures of bacteria from soil and manure these were able to transform nitrate nitrogen into albumen. They, therefore, demonstrated the ability of these bacteria to assimilate nitrate nitrogen.

According to Gottheil (29) the spore forming bacteria, *B. subtilis*, *petasites*, *asterosporus*, *ruminatus*, *tumescens* and *graveolens*, readily assimilated the ammonia of ammonium tartrate while *B. ellenbachensis*, *mycoides*, *pumilus*, *simplex*, *cohaerens*, *carotarum* and *fusiformis* are not able to assimilate to any extent the ammonia of ammonium tartrate.

Bierema (30) in an article entitled: "The assimilation of ammonia, nitrate and amid nitrogen by microorganisms", claims that the utilization of most nitrogen compounds occurs both in pure and mixed cultures when the appropriate carbohydrate is present as a source of energy.

Von Suchtelen (31), gives the results of experiments in which he attempts to measure the intensity of the activity of soil microorganisms by the rate of liberation of CO_2 . There was tested by this

method the effects of pulverization, aeration, water content, frost and the addition of dextrose, mannit, straw and minerals and partial sterilization by CS_2 upon the bacterial activities and evolution of CO_2 . The amount of CO_2 liberated was checked by plate counts and in many instances approximately equivalent results were obtained. He claims that by the CO_2 method he can determine accurately the important factors which influence bacterial life of the soil, especially under field conditions.

Brown (42) investigated sulfification in soils and states that the addition of carbohydrates to the soil depresses sulfification, the greater the amount of carbohydrate added the greater the depression of sulfification. The depression varies in the inverse ratio to the solubility of the carbohydrate.

ASSIMILATION OF PHOSPHATES.

McDowell (32) mixed 6 pounds of raw Tennessee rock in a barrel with 228 pounds of mixed manure and buried the barrel and contents in a manure heap from July 1907 to August 1908. No increase in either water or citrate soluble phosphates occurred.

The biological absorption of phosphoric acid in soils was studied by Dushechkin (33). He concludes, that aside from the Physico-chemical absorption of phosphoric acid, there is a biological absorption. The latter increased with increased additions of starch and length of time. The larger the addition of phosphoric acid, the more there was absorbed. The addition of NaNO_3 increased the consumption of phosphoric acid. Both soluble and insoluble phosphates were absorbed.

Fleischer (34), working with fermenting mixtures of composts of varying portions and ground phosphorite, found, at the end of 18 and 38 weeks that in most instances there was a decrease rather than an increase of water soluble phosphoric acid. In another set of experiments of 6 month's to one year's duration, this investigator found no appreciable increase in the water soluble phosphoric acid.

Lupton, (35), testing the effect of fermenting cotton seed and cotton seed meal with ground South Carolina phosphate rock, found no appreciable increase in the availability of the phosphate.

On the other hand, Egorov (36), working with different kinds of stable manure, as sources of phosphoric acid, notes a large increase in the amount of insoluble phosphoric acid in fermenting manures.

Behrens (37) is responsible for the statement by Lafar that microorganisms of stall manure are capable of cleaving organic compounds in such a way as to render the phosphoric acid and other ash constituents available so that the constituents may be utilized in the metabolism of their own cells.

Stoklasa (38) reports that bacterial cultures growing on media, supplied with various insoluble phosphates, may assimilate as much as 25% of the total phosphoric acid in tricalcium phosphate or commercial phosphates, providing suitable carbohydrates are present.

McNeal (39), working with fresh human faeces is responsible for the statement that as much as 50% of the total dry matter of the

faeces may be dead or living bacterial cells. This gives us some idea of the amount of phosphates and minerals that may be held as bacterial organic matter.

Tottingham and Hoffman (40) subjected rock phosphates and acid phosphates to the action of fermenting manure from 3 to 6 months and found there was a marked decrease in the amount of water soluble phosphates in manure alone or in mixtures with either rock phosphate or acid phosphate. The addition of either chloroform or formaldehyde in quantities sufficient to practically inhibit bacterial action greatly reduced the decrease in water soluble phosphates in such mixtures of manures and floats, indicating that loss of phosphates during fermentation was due to consumption of phosphates by bacteria.

Pot tests with barley confirmed the results of the laboratory. A 37% greater yield of grain was secured by the simultaneous application of fermented manure and soluble phosphate than by the use of a mixture of manure and soluble phosphate which had previously undergone fermentation. A second crop grown upon the same soil without further fertilization reversed the above crop yield, thus indicating that the phosphate previously rendered insoluble by bacterial assimilation was now available to the crop. Similar results were obtained by the use of fermented and unfermented mixtures of manure and rock phosphate.

DISCUSSION OF PREVIOUS WORK

The earliest work on plant food consumption by microorganisms consisted mostly of work with fermenting manures and observations on transformation of ammonia and nitrate nitrogen to protein substances, and occasionally investigations on the effect of decaying organic matter; chiefly manure, upon the solubility of phosphates. The results usually indicate that there is no increase in the water soluble phosphates but often a decrease. As systematic bacteriology and mycology developed, investigations were made to ascertain the nitrogenous compounds which would serve as a source of nitrogen for bacteria and molds. As a consequence, there is now a considerable literature bearing upon the carbon as well as the nitrogen requirements of molds and, to a less extent, for bacteria. In the works published during the last two decades, may be found many references to the carbon sources of certain species of bacteria. Although not always clearly stated, the investigators have probably had in mind the carbon for cell construction rather than carbon as a source of energy. Nevertheless, the work along this line by Pere, Beijerinck, Fisher, Schreiber, Gottheil, Neide, Maassen, Duggeli, Gerlach and Vogel (1) has contributed much to our knowledge of the carbon and nitrogen requirements of bacteria. The protein forming bacteria isolated from soil and manure by Gerlach and Vogel was a step in the right direction, but the failure to follow it by more extensive work, showing the relation of these bacteria to soil metabolism and that transformations of ammonia and nitrate nitrogen to protein was common to other organisms as well, has left an impression that the

transformation of ammonia and nitrates to protein is an extremely detrimental process, confined to a class of injurious bacteria. While the knowledge is lacking of just what carbon compounds and what nitrogen compounds will serve as food for a given specie, it is known that certain bacteria, as well as a large number of molds, can use ammonia and nitrate nitrogen, provided they have a suitable source of energy. Moreover, these facts stand out clearly: that under conditions where the medium contains suitable energy material the ammonia and nitrate nitrogen, as well as the water and citrate soluble phosphates, may be severely depleted by microorganisms.

Turning now to a more critical discussion of the preceding references, as they bear upon this investigation, the work of Lernerman (2) and associates, Lutz (3), Ritter (4), Stutzer and Rothe (5), Stoklasa (6), Street (8), Vogel (14), Fousek (15), Gottheil (29) and Bierema (30) dealing with the assimilation and transformation of ammonia and nitrate nitrogen to protein within the cell of the microorganism, has a distinct bearing upon the work cited in the other references. The above named investigators, working with pure or mixed cultures of microorganisms, prove that both bacteria and molds are capable of transforming these nitrogen compounds into cell substance. This conclusion is clearly borne out in many of the references cited by Löhnis (1). Consequently, when there is taken up for consideration the work of Lipman and Brown (9), Lipman and associates (16) and of Van Suchtelen (31), one is in a position to see more clearly the effects of the carbohydrate materials used by those authors. Lipman and Brown, studying the effect of soluble and insoluble carbohydrates upon ammonia and nitrate formation create conditions similar to those in references: 2-3-4-5-6-8-14-15-29-30 and 41. Therefore, one is dealing with a phase of ammonia and nitrate transformation to protein. Indeed this very suggestion is made by Lipman and associates (16). With Van Suchtelen, on the other hand, we have a different manifestation of the same phenomena. This author was measuring the end product of carbon oxidation, therefore, the end product of the reactions to obtain energy. Consequently, it may be assumed there was going on simultaneously with the liberation of the CO_2 the assimilation and transformation of nitrogen to protein. This is borne out by Van Suchtelen's plate counts which in general, checked with CO_2 liberation. The results of Hutchinson and Marr (13) and that of Fred and Hart (19) agree in general with those of Van Suchtelen. Each of these investigators noted an increase evolution of CO_2 with the increase in the number of bacteria. With Hutchinson and Marr an increase in the number of bacteria and an increased evolution of CO_2 took place when they added starch or sugar.

Behrens (37) and Stoklasa (38) believe that bacteria assimilate available phosphoric acid. It is known that phosphates are necessary for the development of microorganisms. The work of McNeal (39), on the other hand, gives an idea of the amount of phosphates that may be transformed into cell constituents by bacteria alone under certain conditions. Furthermore, Stoklasa (38) believes that as much as 25% of tricalcium phosphate or commercial fertilizers may be so transformed in the presence of sufficient energy material, consequently

under suitable conditions, the amount of phosphates consumed by microorganisms may reach considerable amounts.

The direct evidence obtained on the consumption of ammonia and nitrate nitrogen by microorganisms in the presence of suitable energy material enables us to explain, too, the indirect evidence concerning the consumption of phosphates by microorganisms in the presence of excess organic matter. Indeed the explanation of Duschekkin (23), working on the biological absorption of phosphoric acid by soils is in keeping with the above explanation. As this investigator indicates, there is a biological absorption of phosphoric acid that is separate and distinct from physical absorption and the chemical transformations to tribasic forms. In other words, the water soluble and citrate soluble forms of phosphoric acid may be assimilated by microorganisms in the presence of suitable energy material. According to Duschekkin the absorption, that is assimilation, of phosphoric acid increased with the increased addition of starch.

Tottingham and Hoffman (40), working with mixtures of fermenting manure and phosphates, find that the decrease in water soluble phosphates is due to the assimilation of the available phosphoric acid by the bacteria thus agreeing with Duschekkin that the transformation of the available phosphoric acid to unavailable forms is due, in part, at least, to a biological absorption.

McDowell (32), Fleischer (34), and Lupton (35), working with fermenting mixtures and phosphates, for varying lengths of time, note no appreciable increase in the available phosphates. Egorov (36), on the other hand, finds a distinct increase in insoluble phosphates in fermenting manures.

It would be necessary to know the exact conditions of the experiments of McDowell, Fleischer and Lupton before an explanation could be advanced. With Egorov, however, it is clear that the microorganisms are probably responsible for the increase in the insoluble phosphates.

It is now possible to explain the results obtained by Frankfurt and Duschekkin (12), Hutchinson and Marr (13), Patterson and Scott (24), Ehrenberg (26), and of the barley yields obtained by Lipman and associates (16) in their pot tests. Frankfurt and Duschekkin noted that green manures, both legume and non-legume, lowered both the NO_3 and NH_3 content, which probably means that, aside from the effect due to the decrease in moisture noticed by the authors, there was a transformation of the ammonia and nitrates to protein.

Aside from the favorable conditions created for the growth and spread of parasitic and facultative parasitic molds, by the addition of sugar and starch, the consumption of available plant food, at least phosphates, ammonia and nitrates, by microorganism, probably explains in great measure the results of Hutchinson and Marr. These authors noted that an addition of sugar or starch decreased the yield of barley. The decrease was less where there was considerable plant food than where it was rather limited, indicating that the addition of carbohydrates enabled the microorganism to compete with the barley for the available plant food. The competition was regis-

tered by a greater decrease in the yield of barley in the presence of a limited amount of plant food, while it was less marked where there was more plant food.

Professor Prianichnikov, who heard the presentation of the paper by Hutchinson, explained the action of the carbohydrates as follows: "Das Einführen von Kohlenhydrate hat immer ein Durchsetzen der Erntehöhe als Folge, ebenso wirkt auch unzersetztes Stroh. Die Ursache liegt darin, dass durch die Bakterien und Pilze der Nitrattstickstoff wirt zum theil zerstört (denitrificert) zum theil zu Eiweistoffe verarbeitet; dann leiden die Gramineen von N-Mangel, die Leguminosen vertragen aber sehr gut eine Kohlenhydratengabe, ohne zu leiden. Es er scheint, dass in den versuchen von Herren Hutchinson und Marr auch die Erscheinungen der Nitraterzerstörung oder Nitratverbrauch eine wichtige Rolle gespielt haben". Apparently, Prianichnikov believes that denitrification was in this case the principal factor in producing these decreased yields.

The results obtained by Lipman and associates (16) on pot yields of barley, where it was shown that nitrogen recovered by the barley was usually greatest from samples having no carbohydrate and that a greatly reduced yield was obtained in the presence of a carbohydrate,—point clearly to a competition by microorganisms in the presence of a carbohydrate.

In connection with the same, they show that dried blood, tankage and with mixed fertilizers containing nitrogenous organic matter that the percent of organic nitrogen recovered by the barley was usually greater from the samples having the highest percentages of nitrogen. These results probably mean that the samples containing the highest percentage of nitrogen usually contained the lowest amount of energy forming materials. Therefore, during the decomposition of these nitrogenous fertilizers, there was a greater quantity of nitrogen, in the samples high in nitrogen, in excess of the microorganisms requirements than there was in the samples low in nitrogen. Consequently, there was a greater quantity of nitrogen at the disposal of the barley plants. The results obtained by Lutz (3) support this view. He studied the comparative assimilability of ammoniacal salts, amines, and nitrates and concludes that, in general nitrogenous compounds are assimilated by *Aspergillus* and *Pencillium* in proportion to the complexity of their molecules. Thus the results of Lipman and associates (16) and those of Lutz (3) supplement each other. Lutz finds that the amount of nitrogen not assimilated by *Aspergillus* and *Pencillium* was, in general, greatest where the percent of nitrogen was greatest and Lipman and associates find that the amount of nitrogen assimilated by the barley plants was, in general, greatest where the percent of nitrogen was greatest. The nitrogen not assimilated by the test organisms of Lutz was the same as the nitrogen assimilated by the barley plants of Lipman and associates.

Lipman and associates found also that the amount of ammonia recovered from the rice flour and corn meal was about the same with dextrose as without it. On the other hand, wheat flour, linseed meal, cowpea meal, soybean meal and cottonseed meal invariably gave less

ammonia when dextrose was added. The results obtained by these workers are so striking that the table has been copied for the sake of clearness in discussion. It is appended below.

TABLE ON AMMONIFICATION OF VEGETABLE SUBSTANCES IN THE PRESENCE OF DEXTROSE. COPIED FROM PAGE 16, BULLETIN No. 247, NEW JERSEY EXPERIMENT STATION

Soil Portion No.	Organic materials used	Dextrose added gm.	Water added c.c.	Nitrogen in material used mgm.	Ammonia N recovered	
					7 Days mgm.	Average mgm.
1, 2....	4 gms. Rice flour	None	24	40.40	1.39 1.22	1.30
3, 4....	4 gms. Rice flour	2	26	46.40	1.22 1.39	1.30
5, 6....	4 gms. Corn Meal	None	24	51.20	1.22 1.22	1.22
7, 8....	4 gms. Corn Meal	2	26	51.20	1.39 1.22	1.30
9, 10....	4 gms. Wheat flour ..	None ...	24	94.80	4.88 5.23	5.05
11, 12....	4 gms. Wheat flour ..	2	26	94.80	3.48 3.83	3.66
13, 14....	4 gms. Linseed Meal	None	24	247.00	120.06 116.57	118.31
15, 16....	4 gms. Linseed Meal	2	26	247.00	96.88 95.14	96.01
17, 18....	4 gms. Cowpea meal	None	24	156.80	51.23 49.49	50.36
19, 20....	4 gms. Cowpea meal	2	26	156.80	33.11 30.32	31.71
21, 22....	4 gms. Soybean meal	None	24	245.60	133.65 131.21	132.46
23, 24....	4 gms. Soybean meal	2	26	245.60	109.78 106.29	108.03
25, 26....	4 gms. Cottons'd m'l	None	24	246.12	125.98 121.28	123.63
27, 28....	4 gms. Cottons'd m'l	2	26	246.12	98.97 100.37	99.67

An examination of the above table will show that the amount of nitrogen added was .0464 grams with rice flour, .0512 grams with corn meal, .0948 grams with wheat flour, .247 grams with linseed meal, .1568 grams with cowpea meal, .2456 grams with soybean meal and .24612 grams with the cottonseed meal. The percentages of total carbohydrates in these substances is approximately as follows: rice flour 65, corn meal 70, wheat flour 75, linseed meal 36.4, cowpea meal 60, soybean meal 28.3, and cottonseed meal 24.6. Therefore the addition of 4 grams of rice flour would be equivalent to adding 2.6 grams of carbohydrates and .0464 grams of nitrogen as a protein. The addition of 4 grams of each of the other substances would be equivalent to adding the following quantities of carbohydrates and nitrogen as a protein; corn, 2.8 grams carbohydrates and .0512 grams protein nitrogen, wheat 3 grams carbohydrates and .0948 grams protein nitrogen, linseed meal 1.4 grams carbohydrates and .247 grams protein nitrogen, cowpea meal 2.4 grams carbohydrates and .1568 grams protein nitrogen, soybean meal 1.1 grams carbohydrates and .2456 grams protein nitrogen and cottonseed meal .9 grams carbohydrate and .24612

grams of protein nitrogen. The ratio of carbohydrates to nitrogen would be

56 to 1 for rice flour.

15 to 1 for cowpea meal.

54 to 1 for corn meal.

5 to 1 for soybean meal.

32 to 1 for wheat flour.

4 to 1 for cottonseed meal.

6 to 1 for linseed meal.

According to the above proportions there is approximately twice as much carbohydrates in proportion to the nitrogen in the rice flour and corn meal as there is in the wheat flour, almost four times as much carbohydrates in proportion to the nitrogen in the rice flour and corn meal as there is in the cowpea meal and approximately ten times as much carbohydrates in proportion to nitrogen in the rice flour and corn meal as there is in either the linseed meal, soybean meal or cottonseed meal. There is, furthermore, a high percent of starch in the carbohydrates of rice, corn, wheat, cowpea and soybeans. Lipman and associates show in this same work that starch represses the ammonification of dried blood more than sucrose and sucrose more than dextrose. Therefore, the reason why dextrose did not repress the ammonification of rice flour and corn meal was because there was sufficient carbohydrates present in these substances to allow the assimilation of practically all the nitrogen. On the other hand, with wheat there was probably not quite enough readily available carbohydrate present to furnish sufficient energy to consume the larger quantity of nitrogen and the energy furnished by the dextrose enabled the microorganisms to assimilate some of the excess nitrogen. A similar explanation answers for the other substances.

Brown (42) noted a similar effect of carbohydrates upon sulfification in soils and the same explanation probably applies. Likewise, this is probably the reason why Frankfurt and Duschekkin (12), Patterson and Scott (24), Ehrenberg (26), Enberding (27) and Hill (28) noted an inhibitive effect of carbohydrates upon nitrification and also probably the reason why McDowell (32), Fleischer (34), Lupton (35): as explained too by Duschekkin (33), Stoklasa (38) and Tottingham and Hoffman (40), noted an absorption or assimilation of phosphates.

The results secured by Hoffman (18) in his work on nitrogen fixation due to the application of carbohydrates may be explained as follows:

The application of kainits and floats furnished potassium and phosphorus which made a better balanced bacterial medium and thereby favored the development of decay organisms. The decay organisms finding themselves in a better balanced medium, due to the increase in potash and phosphorous, consumed some of the sugar or starch for energy. The consumption of energy material by the decay organisms reduced the amount of energy material available to the nitrogen fixing bacteria. The reduction of energy material was registered as a decrease in nitrogen fixation.

MATERIALS AND METHODS USED

All chemicals used in these investigations were Merk's "Highest Purity". These chemicals were all tested for purity before being used. Only redistilled water was used.

Unless otherwise stated, all tests were run in quadruplicate and repeated at least once. Where variations were observed, either between checks or between first and second determinations, the tests were repeated until the cause of variation was clear.

The cultures were transferred to nutrient broth 72 hours before inoculation. Seventy-two hour growths on nutrient broth were used for all inoculation. Approximately uniform numbers of bacteria were secured by adding 5 grams of quartz sand to each, 10 c.c. of nutrient broth before sterilization. The sand enabled the separation of most cells by agitation.

Chemical determinations were made by standard method (68).

When quantitative determinations were made to estimate the amount of chemical consumed, the amount of the chemical added was always determined by analysis of the medium which had served as control.

Owing to a lack of sufficient incubation room, these determinations were all run at room temperature which unfortunately varied from 22° to 28° C. The fluctuations of temperature sufficed to cause marked variation in degree of reaction. Such for example, as a difference in the amount of ammonia liberated from casein in a given period by *B. mycoides*. Although there was a distinct difference in degree of reaction, there was no change noted in relation of one species to another.

Owing to the fact that most of the data in this bulletin will be used for extensive discussion the probable error has been recorded, wherever practical. Wherever the recording of the error would make too large a table, or where it was impractical because of compilation or arrangement, the grand average error has been recorded below each table. All extreme variations were eliminated, as previously noted. The averages are simple arithmetic averages as the calculation of least squares involved too much work for the data presented in this bulletin.

EXPERIMENTAL WORK

Work with synthetic media (69), using c. p. anhydrous dextrose as a source of energy, proved that *B. subtilis*, *B. mycoides*, *B. megatherium*, *B. proteus*, *B. vulgatus* and *Sarcina lutea* could assimilate ammonia nitrogen.

The medium used had the following composition:

K_2HPO_4	1.00 gm.
$(NH_4)_2SO_4$	1.00 gm.
$MgSO_4$	0.50 gm.
$CaCl_2$	.20 gm.
$NaCl$	.10 gm.
$FeSO_4$	.01 gm.
$MnSO_4$	.001 gm.
Anhydrous Dextrose	5.00 gm.
Water, double, distilled from glass retort and condenser	1000.00 gm.

To facilitate discussion this medium will be known as No. 1.

The reaction of the medium was + .4%.

After sterilization, 1 c.c. of a 72 hour culture was transferred into a 2000 c.c. Erlenmeyer flask, containing 400 c.c. of the medium. Growth occurred within 48 hours to 96 hours depending upon the organisms and upon the temperature. Tests were run seven days.

Quantitative determinations* were made to ascertain the amount of ammonia assimilated per gram of dextrose consumed.

The amount of ammonia assimilated was determined by the difference between that added and the amount recovered as ammonia at the end of the experiment. These determinations were made upon 400 c.c. portion of the medium, by the MgO. method (68). Therefore, all figures on ammonia determination must be taken as relative and not absolute. The difference was determined as follows: Four 400 c.c. portions of the medium were used as controls. At the end of the experiment the ammonia present in these was determined. This was assumed to be the ammonia added. The ammonia present in the four inoculated quadruplicates was then determined. The ammonia present in the latter subtracted from the ammonia present in the former was assumed to give the ammonia consumed. It was assumed that no nitrogenous compounds capable of liberating ammonia in the presence of MgO was secreted into the medium by the growing bacteria.

Analysis of the total nitrogen was made by the Kjeldahl method modified to include nitrates (68).

The dextrose consumed was estimated by determining the dextrose that remained at the end of the experiment in 10 c.c. of cleared, filtered medium from the control flasks. This was considered the amount of dextrose added. The amount of dextrose that remained in 10 c.c. of cleared filtered medium from an inoculated flask was subtracted from the amount added to give the amount consumed.

The method employed was direct weighing of cuprous oxide. Treatment and Results are given in Table I.

TABLE I. DEXTROSE AND AMMONIA CONSUMED BY BACTERIA AT ROOM TEMPERATURE 22 TO 29 C. CALCULATIONS MADE FOR 100 C. C.

Organism	Appearance	Mgm. dextrose consumed	E	Mgm. NH ₃ assimilated	E	Mgm of NH ₃ assimilated per gram of dextrose	Total N at beginning mgm.	Total N at close mgm.
<i>B. subtilis</i>	Flocculent precipitate	300	.4	2.	1.1	6.6	210.9	211.9
<i>B. proteus</i>	Heavy turbidity	612	1.0	4.	1.0	6.5	"	210.7
<i>B. mycoides</i>	Heavy flocculent precipitate	650	1.5	6.	1.1	9.2	"	211.0
<i>B. megatherium</i>	Turbid with sediment	320	.5	12.	.9	37.4	"	211.4
<i>B. vulgatus</i>	Membrane	545	.5	17.5	.4	32.1	"	210.0
<i>Sarcina lutea</i>	Vidid sediment	410	1.9	5.	1.7	12.1	"	210.3
Control (70).....	Clear	None		None		None	"	210.0

*Nessler's Reagent cannot be used in the presence of dextrose, levulose, or galactose. With these sugars, Nessler's gives a reaction which at first strongly resembles the ammonia reaction, but later slowly changes to resemble the aldehyde reaction with Nessler. Therefore, direct colorimetric determinations of ammonia could not be made.

Unpublished notes on Synthetic media (70) show that check determinations with each organism using the above medium without dextrose gave negative results. The same was true with each organism when inoculated into the above medium without ammonia.

The results in the second column of Table I show distinctly that a growth takes place. Columns 3 and 5 show that the growth is accompanied by a disappearance of dextrose and ammonia, but with no decrease in total nitrogen, as may be seen by columns 8 and 9. Since there was a disappearance of ammonia with no loss of nitrogen, it appears that the growth of the bacteria must have caused the ammonia to be transformed into some nitrogenous compound which would not liberate the nitrogen as ammonia during the period of distillation with MgO . In order to guard against the possibility of oxidation of ammonia to nitrates, qualitative tests* were made. All tests for nitrates were negative. Consequently the ammonia did not remain in the medium as a salt of ammonia nor as a nitrate. Therefore, bacterial growth must have resulted in part of the ammonia being transformed into some complex form. Since there was no other form of nitrogen present in the medium excepting ammonia, and since the bacteria must have nitrogen in order to develop they must have assimilated the nitrogen of ammonia. Nitrogen fixation did not take place.

The results in column 7, Table I, must not be regarded as absolute because of the great variation in temperature.

Likewise, no attempt was made to determine the possible extracellular enzymic action which might reduce some dextrose to a non-reducing body, thus giving it the appearance of having been consumed as energy or building material when its disappearance may have been due to purely enzymic action independent of energy consumption by the bacterial cell. Neither was an attempt made to detect or measure the possible formation of aldehydes from the dextrose. As aldehydes reduce Fehlings solution, they would, if present, make it appear that less dextrose had been consumed than was really the case.

The fundamental problem underlying this study of assimilation of ammonia by bacteria, aside from a suitable source of energy, is the unit of energy required by any one organism per unit of ammonia assimilated. Since the action of these organisms upon dextrose resulted in the formation of lower compounds, which still contain considerable of the original potential energy of the dextrose, it cannot be said that column 3 represents the amount of potential energy in terms of dextrose necessary to assimilate the amount of ammonia in column 5 but only the amount of dextrose which these organisms reduced to lower compounds in order to obtain the requisite energy. The actual amount of energy involved remains undetermined. This point has been excellently presented by Rahn (43) on food of micro-organisms. He writes: "The total energy stored in an organic compound is measured by the amount of heat liberated by its complete combustion. One gram of dextrose produces 3750 calories, if burned to carbon dioxide and water. The plant producing this dextrose from

*Brown Ring, Diphenylamine and Brucine tests.

carbon dioxide and water needs, therefore, 3750 calories for every gram made, which are taken from the radiant energy of the sun. The mold oxidizing one gram of dextrose completely, gains in this process 3750 calories which may be used in form of chemical energy for its growth and for building up the complex compound of cell life from small, simply constructed molecules. If the mold has ceased growing, these 3750 calories will not be used, but will produce a slight rise in the temperature of the nutrient medium. A yeast fermenting the dextrose to alcohol and carbon dioxide does not use the entire energy of the dextrose; there is considerable available energy left in the alcohol; carbon dioxide contains no available energy. One gram of dextrose gives about .48 gram of alcohol and .52 gram of carbon dioxide. The heat of combustion of alcohol is 7183 calories per gram or 3476 calories for 0.48 gram. The heat of combustion of carbon dioxide is nil. The dextrose before fermentation contained 3750 calories, the products of fermentation contained 3476 calories; the yeast, therefore, gains by the fermentative process only 274 calories from 1 gram of dextrose. This is a very small gain compared with that of oxidation, the ratio is 274:3750 or 1:14. This means that a yeast, in order to get the same supply of energy as an oxidizing mold, has to ferment fourteen times as much sugar as the mold oxidizes''.

There are several factors which influence the rate of dextrose consumption per milligram of NH_3 assimilated. As a general rule, more dextrose is consumed per mgm. of NH_3 assimilated at low temperatures than at high. Likewise aeration greatly affects the relation between dextrose and ammonia consumption. Moreover, if certain organisms secrete extra cellular enzymes which are capable of decomposing dextrose into acids or gas, these will prove wasteful users of dextrose. In the presence of a large excess of dextrose, it is consumed in larger quantities per gram of NH_3 than in the presence of a large excess of NH_3 .

Having established the fact that the test organisms consume NH_3 when dextrose is present, as a source of energy, they were next tested for their ability to produce ammonia from casein in synthetic solution and from casein in the presence of dextrose. Casein was selected because it may be obtained reasonably pure; is a definite chemical compound, and that which remains in the medium at the end of the experiment can be determined with some degree of accuracy. Consequently the amount of casein decomposed by an organism, under definite conditions, in order to liberate a given amount of ammonia, may be assumed to be the difference between the amount of casein added and the amount of casein that remains in the medium at the end of the experiment. The medium for this work was the same as medium No. 1, excepting that casein was substituted for $(\text{NH}_4)_2\text{SO}_4$.

Brown (44) has shown that casein serves as a suitable ammonifiable substance for measuring the ammonifying power of soils. The method used by Brown for putting casein in solution was found

quite satisfactory. The medium used in these experiments had the following composition.

	Grams
K_2HPO_4	1.00
Casein	5.00
$MgSO_4$	.50
$CaCl_2$	.20
$FeSO_4$	.01
$MnSO_4$	.0001
Distilled water	1000 c.c.
Dextrose, when used, was added at the rate of 5 grams per liter.	
Reaction adjusted to + .5%.	

The above medium is No. 2

2—A, Casein only.

2—B, casein and dextrose.

The exact procedure for making the above medium was as follows: All the chemicals used in medium No. 1 excepting $NaCl$, K_2HPO_4 and the nitrogen were added to about 15 liters of distilled water. One hundred grams of Merck's casein was then dissolved in 4 liters of approximately .06 N. $NaOH$. The casein solution was added with constant stirring to the 15 liters of water. The entire solution was then made slightly acid by the addition of $N. HCl$. While adding the HCl , vigorously stirring was maintained. This completely breaks up any casein precipitate. The requisite amount of K_2HPO_4 was then added and the medium diluted to 20 liters after which the reaction was adjusted to + .5% acid. The medium was then divided into two 10 liter portions. One of the 10 liter portions received 50 grams of c. p. anhydrous dextrose.

These media were then measured out in 600 c. c. portions in two liter erlenmeyer flasks, plugged and sterilized in the autoclav at 10 lbs., for 15 minutes, after which they were allowed to stand at least 72 hours at room temperature before inoculation. Inoculations were made by transferring 1 c.c. of 72 hour boullion culture to each flask. Two controls were run for each medium. The amount of casein and dextrose present in the controls at the end of the experiment was considered the amount of these substances in the medium at the begining of the trial. The results are given in Table II.

At the beginning of the work with the dextrose medium, very unsatisfactory results were obtained when the room temperatures reached almost $29^{\circ} C$. At this temperature *B. subtilis* produced sufficient acid in 48 to 72 hours to precipitate the casein and retard bacterial action. The same was true with *B. mycoides* and *B. proteus* from 72 to 96 hours. The difficulty was finally overcome by adding to each flask 5 grams of finely ground c. p. $CaCO_3$. The same amount of $CaCO_3$ was added to the flasks which contained only casein. All flasks were stirred by rotating equal number of times each morning and evening.

The results in Table II show that dextrose in some way retards the accumulation* of ammonia in the medium. Such retardation may be due either to dextrose inhibiting the growth of bacteria, loss of NH_3 from the medium, splitting the casein into amino acids without the liberation of ammonia or the assimiltion of the ammonia liberated.

*As pointed out later, there is a difference between ammonification as we now define it and ammonia accumulation.

TABLE II. THE EFFECT OF DEXTROSE UPON THE AMMONIFICATION OF CASEIN BY PURE CULTURES OF BACTERIA, INCUBATION PERIOD SIX DAYS

Organism	Treatment	Mgm. NH_3	N	Difference due to dextrose
<i>B. subtilis</i>	Casein	34.4	.85	
<i>B. subtilis</i>	Casein & dextrose	9.8	.95	24.8
<i>B. proteus</i>	Casein	15.2	1.05	
<i>B. proteus</i>	Casein & dextrose	3.6	1.00	11.6
<i>B. mycoides</i>	Casein	72.8	.50	
<i>B. mycoides</i>	Casein & dextrose	3.6	.75	69.2
<i>B. megatherium</i>	Casein	19.2	.15	
<i>B. megatherium</i>	Casein & dextrose	9.6	.85	9.6
<i>B. vulgatus</i>	Casein	29.0	.80	
<i>B. vulgatus</i>	Casein & dextrose	11.0	.80	19.0
<i>S. lutea</i>	Casein	57.2	.92	
<i>S. lutea</i>	Casein & dextrose	9.6	.74	47.6

If there is a loss of nitrogen from the medium, it can be estimated by a total nitrogen determination. If there is an inhibitive effect exerted by the dextrose the inhibitive effect can be measured directly by making a total count of the bacteria and comparing the number of those found with those in casein alone. If dextrose exerts an inhibitive effect on bacterial development, there should be but slight, if any, decomposition of the casein. On the other hand, if there is an increased bacterial growth, a decrease in dextrose and casein with no loss of total nitrogen, there being no increase in ammonia accumulation and no nitrate formation, it should go far to indicate that the ammonia which was liberated from the casein was assimilated by the growing bacteria. In order to test out these theories, media 2 A. and 2 B. were again prepared and inoculated as in the preceding experiment.

The nitrogen present at the beginning was determined by analysis of the control flasks.

Casein determinations were made by the official method (68), after filtering the medium through filter paper to remove bacterial membranes. Unquestionably there were many bacterial cells still left in suspension and large numbers of these were carried down by the casein precipitate. In order to free the casein precipitate as much as possible from the bacterial cells, it was dissolved in approximately N/20 NaOH and reprecipitated with acetic acid. It was found necessary to thoroughly comminute the precipitate from the flasks containing dextrose before it would go into solution.

Total counts of bacteria were made on standard (45) nutrient agar. Extreme difficulty was experienced in getting agreement between checks for total counts because of the heavy membranes formed. This was finally overcome by weighing out 100 grams pure quartz sand into quart Mason jars. To these jars were then added 200 c. c. media 2-A or 2-B as required. These jars were plugged with cotton sterilized and inoculated as above. At the end of the experiment the cotton plugs were removed and the sterile caps, with rubbers, were screwed on. These jars were then shaken in the shaking machine for 30 minutes. After allowing the sand to settle, the counts were made by proper dilution.

Turning now to Table III, it becomes apparent from columns 3 and 4 that there was no loss of nitrogen. In column 5 the dextrose exerted

TABLE III. RESULTS OF 6 DAYS INCUBATION AT ROOM TEMPERATURE USING 400 C.C. OF A SYNTHETIC NUTRIENT SOLUTION WITH CASEIN AS A SOURCE OF NITROGEN AND WITH CASEIN AND DEXTROSE

Organism	Treatment	Mgm. of N at beginning	Mgm. of N at close	Mgm. of ammonia accumulated	Mgm. difference due to dextrose	Mgm. casein consumed	Mgm. casein per mgm. NH ₃	Calculated mgm. of NH ₃ liberated	Calculated NH ₃ consumed	Dextrose consumed	Bacteria in million
B. subtilis.....	Casein	577.4	578.0	43.		2109.1	49.0	43.			28.8
B. subtilis.....	Casein dextrose	"	577.0	11.9	21.1	1874.1		38.2	26.0	1934	42.6
B. proteus.....	Casein	"	578.6	13.6		2054.4	151.0	13.6			62.4
B. proteus.....	Casein dextrose	"	578.0	2.6	11.0	1716.4		11.3	8.7	1771	67.75
B. mycoides.....	Casein	"	577.0	64.9		1459.0	22.4	64.9			50.2
B. mycoides.....	Casein dextrose	"	577.0	14.3	50.6	1001.0		44.6	30.3	1885	61.0
B. megatherium..	Casein	"	578.4	20.8		2055.2	98.8	21.1			57.8
B. megatherium..	Casein dextrose	"	578.1	10.5	9.6	2086.5		20.4	9.9	1864	87.9
B. vulgatus.....	Casein	"	577.2	32.0		1734.9	54.2	32.0			91.4
B. vulgatus.....	Casein dextrose	"	577.3	16.7	15.3	1773.1		32.7	16.0	1988	111.2
S. lutea.....	Casein	"	577.0	28.4		829.5	29.2	28.8			14.7
S. lutea.....	Casein dextrose	"	578.0	9.2	19.6	900.0		30.8	21.6	1565	15.6
Average error.....		.25	.9	.65		13.2				1.3	.440
Maximum error.....			1.7	1.95		33.4				4.8	.715
Minimum error.....			.1	.25		1.2				.1	.200

a distinct depression upon the accumulation of ammonia. In column 6, the depression is seen to vary from 11 to 50.6 mgm. The question now arises: was the depression real or only apparent, i. e., did the addition of dextrose really lessen the amount of ammonia liberated or did the presence of dextrose enable the bacteria to assimilate part of the ammonia liberated? In all cases, there was a marked decomposition of casein. In column 7 it may be seen that dextrose caused a distinctly smaller decomposition of casein with *B. subtilis*, *B. proteus* and *B. mycoides*. While there appears to be a greater decomposition of casein in the presence of dextrose with *B. megatherium*, *B. vulgatus* and *S. lutea*. Unfortunately these relations did not always hold true. In some instances distinctly more casein was decomposed in the presence of dextrose for all the organisms and in other instances distinctly less. Where room temperature ran high, the dextrose was completely consumed before the end of the experiment. It is therefore impossible to confirm the work of Kendall and Walker (65) with *B. proteus*. but the results of these workers on ammonification (66) is confirmed. Table III is the average of 17 separate tests in which each organism was run in quadruplicate. In other words: the figures 2109.1 at the top of column 7 is the average milligrams of casein decomposed by *B. subtilis* in the absence of dextrose in 68 separate inoculations. Nevertheless, there was in every instance, a marked decomposition of casein, both in the presence and in the absence of dextrose. This would indicate marked bacterial action. See column 12, Table III. It should not be considered phenomenal that some

bacteria decompose more casein in the absence of dextrose than they do in its presence, even though the dextrose was not toxic. but distinctly beneficial because in the absence of dextrose the casein must serve not only as a source of nitrogen but also a source of energy. Consequently when casein was used alone and when the demand for both energy and nitrogen must be furnished by the casein, it would naturally result in an accelerated casein decomposition, even though the enzymic action which decomposed the casein, so as to furnish the necessary energy, resulted, at the same time, in the liberation of the nitrogen in an assimilable form. It is possible, as demonstrated in Table I, that these organisms can utilize NH_3 as their sole source of nitrogen, and the decomposition of the casein was as essential in order to obtain energy as it was to obtain nitrogen. The decomposition resulted in some of the nitrogen of the casein being liberated as ammonia which was an end product of enzymic action. The growing bacteria assimilated such NH_3 as they need for growth. The ammonia nitrogen which was in excess of the needs of the bacteria would remain in the medium. Consequently, when 2109.1 mgm. are decomposed by *B. subtilis*, there is left in the medium 43 mgm. of NH_3 in excess of the bacterial food requirements. The ammonia is readily soluble and may be assimilated by this organism, up to a certain dilution, whenever a suitable source of energy is present. In this case the limit of dilution* with *B. subtilis* in the presence of abundant energy was 11.9. of NH_3 per 400 c. c. or approximately .002975%. Therefore, when dextrose was present *B. subtilis* utilized sufficient dextrose to assimilate all but 11.9 mgm. of NH_3 . In support of this view see Table IV.

These results may be approached from another viewpoint. In the absence of dextrose, *B. subtilis* decomposed 2109.1 mgm. of casein and liberated 43 mgm. of NH_3 . By dividing 2109.1 by 43, we obtain 49.04 as a quotient; therefore, within the limits of this experiment, *B. subtilis* in the absence of dextrose, produces 1 mgm. of NH_3 from 49.0 mgm. of casein. It may be assumed that the decomposition of casein followed the same lines of cleavage in the presence of dextrose as it did in the absence of dextrose, because the decomposition, in each instance was probably brought about by the same enzymes otherwise there would not be even a small amount of ammonia in the presence of dextrose. Therefore, by the above figures, it is possible to calculate the milligrams of ammonia that should have been obtained from the decomposition of casein in the presence of dextrose, if it had not been consumed.

In the presence of dextrose, *B. subtilis* decomposed 1874.1 mgm. of casein. According to the above ratio of 1 mgm. of NH_3 to 49.0 mgm. of casein there should have been produced from the 1874.1 mgm. of casein 38.2 mgm. of NH_3 , whereas only 11.9 mgm. were obtained. Therefore, the difference between the amount of ammonia present in the dextrose medium and the amount that should have been, i. e. $(\frac{1874.1}{49} - 11.9)$ or 26 mgm. must have been assimilated by the bacteria. This assump-

*The concentration was perhaps less than .002975% because with the MgO method there was unquestionably some NH_3 obtained from other than ammonia compounds.

tion is supported by the results in columns 11 and 12. In column 11 there is shown with each organism a distinct disappearance of dextrose. The amount of dextrose decomposed is great enough to show that in some way its disappearance was associated with the development of the bacteria.

It is known that these organisms need energy; therefore, it is assumed that the dextrose was used as a source of energy and the casein was decomposed just fast enough to supply the nitrogen. Ammonia nitrogen, equivalent to the amount found in the absence of dextrose, may not have reached the ammonia stage. In the presence of dextrose, but may have been assimilated as amino acids. In either case the action of the energy material, dextrose, was to increase the assimilation of nitrogen by the bacteria, and to decrease the amount of ammonia accumulated. Therefore, while dextrose may be said to inhibit ammonia accumulation, it cannot be said to inhibit the development of the ammonifying bacteria or the consumption of nitrogen. Column 12 furnished data for the final argument in favor of the theory that the presence of dextrose causes the assimilation of the nitrogen that would otherwise accumulate as ammonia. In each instance a greater number of bacteria is found with the dextrose than with casein alone. Now, a greater number of bacteria will require more nitrogen than a lesser number. Therefore, the nitrogen liberated from the decomposed casein must have been either assimilated in some amide form or as ammonia. In either case, the effect of dextrose upon ammonification has the same practical effect when we consider the free ammonia as potential plant food.

It will require quantitative results on all transition products to settle these questions. Quantitative determinations conducted under exact conditions must account for all the nitrogen. The work of Kendall and Walker (65) with *B. proteus* suggests that there is need of investigating the time that it takes the proteoclastic enzyme which attacks casein to make its appearance. If it can be shown that the proteoclastic enzyme does not make its appearance in the medium until after the disappearance of the dextrose, it will go far to show that the need of energy and not nitrogen, is the controlling factor in ammonification.

Table IV contains the data secured in one of the tests on the influence of dextrose on casein ammonification and is given to show the close relation between the calculated ammonia assimilated, see column 7, and dextrose actually consumed and also, the ammonia which accumulated in the dextrose casein medium, see column 4. On comparing columns 5 and 7, it is apparent that for each organism there is a close relation between the dextrose consumed and the calculated ammonia consumed. The more dextrose consumed the greater the calculated amount of NH_3 assimilated. There is also a close relation between the ammonia accumulated and dextrose consumed. However, there seems to have been the greater ammonia accumulation where the dextrose consumption was lowest. The data is almost distinctive enough to say that ammonia accumulation was inversely proportional to dextrose consumption and "calculated ammonia" assimilation was directly proportional to dextrose consumption. Such a condition

TABLE IV. TABLE SHOWING THE RELATION OF AMMONIA ACCUMULATED IN THE PRESENCE OF DEXTROSE AND AMMONIA CONSUMPTION

Organism	No. of flask	Treatment	Ammonia found mgm.	Dextrose consumed mgm.	Average	Calculated ammonia consumed mgm.	Average	Mgm. of casein per Mgm. of NH_3
<i>B. subtilis</i>	5	Casein	6.4	1865		32.		41.0
<i>B. subtilis</i>	6	dextrose	6.0	1872		34		41.0
<i>B. subtilis</i>	7	"	6.8	1879		34.5		41.0
<i>B. subtilis</i>	8	"	6.1	1891	1876.7	37.4	34.4	41.0
<i>B. proteus</i>	13	"	12.1	1920		13.0		160.0
<i>B. proteus</i>	14	"	13.0	1900		12.8		160.0
<i>B. proteus</i>	15	"	12.2	1935		13.4		160.0
<i>B. proteus</i>	16	"	13.8	1915	1917.5	13.0	13.0	160.0
<i>B. mycoides</i>	21	"	13.6	1949		50.5		29.4
<i>B. mycoides</i>	22	"	13.0	1948		50.0		29.4
<i>B. mycoides</i>	23	"	13.0	1956		52.0		29.4
<i>B. mycoides</i>	24	"	13.9	1940	1948.2	50.0	50.6	29.4
<i>B. megatherium</i>	29	"	11.2	1870		22.1		96.0
<i>B. megatherium</i>	30	"	12.9	1850		21.8		96.0
<i>B. megatherium</i>	31	"	13.8	1855		21.0		96.0
<i>B. megatherium</i>	32	"	13.7	1850	1856.2	20.6	21.3	96.0
<i>B. vulgatus</i>	37	"	16.9	1940		30.		45.0
<i>B. vulgatus</i>	38	"	17.4	1900		33.5		45.0
<i>B. vulgatus</i>	39	"	16.9	1942		29.5		45.0
<i>B. vulgatus</i>	40	"	17.7	1989	1967.7	31.0	31.	45.0
<i>S. lutea</i>	45	"	9.1	1610		27.5		42.0
<i>S. lutea</i>	46	"	10.2	1580		25.4		42.0
<i>S. lutea</i>	47	"	9.9	1582		26.0		42.0
<i>S. lutea</i>	48	"	11.7	1524	1524.0	24.4	25.8	42.0

The above table is compiled from one of the tests from which Table III was made. Each of the dextrose determinations is an average of duplicate determinations.

admirably fits the theory that ammonia is assimilated in the presence of dextrose. The difference is so slight, however, that it might be due to error of the MgO method for ammonia determination. The only explanation that seems adequate is that for every gram of dextrose consumed there was a definite number of milligrams of ammonia nitrogen assimilated.

The milligrams of ammonia assimilated per gram of dextrose consumed is shown in column 3, Table V. Here it will be noted that in the casein dextrose medium more ammonia was assimilated per gram of dextrose consumed than when dextrose and ammonia sulphate

TABLE V. COMPARATIVE ASSIMILATION OF AMMONIA FROM $(\text{NH}_4)_2 \text{SO}_4$ IN THE PRESENCE OF DEXTROSE AND THE ASSIMILATION OF AMMONIA FROM CASEIN IN THE PRESENCE OF DEXTROSE

	Dextrose and $(\text{NH}_4)_2 \text{SO}_4$ mgm. of NH_3 per gm. of dextrose	Dextrose + casein mgm. of NH_3 per gram dex. consumed
<i>B. subtilis</i>	6.6	54.6
<i>P. proteus</i>	6.5	147.4
<i>B. mycoides</i>	9.2	38.5
<i>B. megatherium</i>	37.0	87.5
<i>B. vulgatus</i>	32.0	63.4
<i>S. subtilis</i>	12.1	61.0

Compiled from column 7, Table I, and columns 6 and 8 Table IV.

were used. See column 2. A possible explanation of this difference may be due to the fact that with the casein dextrose medium the organism had at its disposal both these substances as a source of energy and building material and could make a more economical use of the energy.

Coleman's (10) work indicates that small amounts of organic matter favor nitrification. According to Karpinski and Niklewski (11) small amounts of organic matter such as is furnished by soil extracts, humates and acetates and even peptone and sugars favor nitrification in mixed cultures. It was, therefore, planned to test the influence of a small amount of dextrose upon ammonification of casein. For this purpose media 2-A was used with increasing quantities of dextrose. The results are shown in Table VI:

The data in Table VI shows that .05% of dextrose increases the ammonification of casein with *B. subtilis*, *B. proteus* and *B. vulgatus*, but distinctly depresses the accumulation of ammonia with *B. mycoides* and *B. megatherium* and *Sarcina lutea*. There is distinctly less ammonia with .1% dextrose in all cases and even more marked depression with .2%.

TABLE VI. MILLIGRAMS OF AMMONIA PRODUCED IN 400 C.C. OF MEDIA 2-A AND MEDIA 2-A WITH INCREASING QUANTITIES OF DEXTROSE, 6 DAY INCUBATION PERIOD AT ROOM TEMPERATURE

Organism	Mgm. NH ₃ from casein alone	Mgm. NH ₃ from casein plus .05% D.	Mgm. NH ₃ from casein plus .1% dextrose	Mgm. NH ₃ from casein plus .2% dextrose
<i>B. subtilis</i>	39.3	52.0	36.4	11.0
<i>B. proteus</i>	56.4	73.4	43.6	15.9
<i>B. mycoides</i>	71.8	48.6	35.2	17.0
<i>B. megatherium</i>	34.1	27.2	26.4	18.2
<i>B. vulgatus</i>	38.9	47.9	30.6	20.0
<i>S. lutea</i>	33.8	28.0	24.4	12.0

If only *B. mycoides*, *B. megatherium* and *Sarcina lutea* are considered it would appear as though the dextrose exerted a depressing effect. However, when *B. subtilis*, *B. proteus* and *B. vulgatus* are considered it appears that dextrose exerted a stimulative effect. The following explanations may throw some light upon the action. Dextrose was added in the following amount: .05%, .1% and .2%. These percentages of 400 give this quantity of media, respectively, the following amount of dextrose 200 mgm., 400 mgm. and 800 mgm. The smallest amount of dextrose consumed in Table IV was 1524 mgm. and the largest 1967 mgm. Hence, there was sufficient dextrose present where .2% was used to allow the consumption of large quantities of NH₃.

The first and most logical explanation that suggests itself is the greater energy requirement of *B. subtilis*, *B. proteus* and *B. vulgatus*. If these three organisms required more energy to consume 1 mgm. of ammonia than the three remaining organisms, it is conceivable that the .05% dextrose would be consumed earlier in the period of incubation. There would be, therefore, more time for the accumulation of ammonia. As a supplement to this idea we must, of course, assume a greater bacterial development in the presence of dextrose than with

casein alone. Unfortunately, column 7, Table I, does not consistently support the view of a greater energy requirement. As previously pointed out, however, the evidence at hand does not indicate the amount of energy required by each organism. On the other hand, if it is assumed that *B. subtilis*, *B. proteus* and *S. lutea* can use dextrose as a source of energy more readily than casein, there would be a more rapid multiplication of these bacteria in the presence of dextrose than in its absence since the excess ammonia nitrogen liberated from the casein, and with the dextrose would furnish a more suitable medium than casein alone. Under this condition the ammonia would be constantly used to the lowest limit of dilution and the casein would be decomposed under the spur of nitrogen need only*.

Consequently, as long as the dextrose lasts, a condition exists analagous to having two media. For the sake of clearness, imagine that the media are in separate flasks. Thus there would be multiplication of the bacteria progressing in the dextrose ammonium medium and also in the casein medium. If dextrose is not toxic, multiplication of the bacteria, using casein as a source of energy, would proceed almost as rapidly as though dextrose was not present. Likewise, the bacteria using dextrose as a source of energy should multiply as rapidly as if casein was not present, providing, ammonia is furnished rapidly enough. If such were the case, one would expect to find a number of bacteria present in the casein dextrose medium approximately equal to the sum of those present in a casein medium and a dextrose ammonium medium, or by making a total count. one would expect to find present in the dextrose casein medium more bacteria than in the casein medium. This ratio would hold until the number approached the maximum, as long as there was available dextrose present. When the dextrose was exhausted, or after it had decreased in quantity, so that it no longer furnished an adequate supply of energy for those bacteria assimilating free NH_3 , one would expect to find a much larger number of bacteria attacking the casein in the casein dextrose medium than in the casein medium, providing of course that the bacterial numbers had not reached maximum before the exhaustion of the dextrose. If there was present at the beginning only a small quantity of the dextrose so that it would become exhausted early in the period of incubation, one might expect this greater number of bacteria to ammonify a sufficiently greater quantity of casein so that the ammonia liberated during the experiment, minus that assimilated by the bacteria, using dextrose as a source of energy would leave a greater amount of ammonia in the casein dextrose medium than there would be in the casein medium. Likewise, one would expect a total count early in the period of incubation to show a greater difference in numbers of bacteria present in the dextrose casein medium than in the casein medium, than one would at the end. On the other hand, if *B. mycoides*, *B. megatherium* and *S. lutea* can utilize casein as a source of energy more easily than they can dextrose, one would expect to find the decomposition of casein progress as rapid in the presence of dextrose as in its

*Such a view would conform to the more exact experimental results secured by Kendall and Walker (65).

absence. In this case, the dextrose would be utilized just fast enough to furnish energy for the assimilation of the nitrogen that would otherwise remain in the medium as ammonia. The dextrose would serve to supplement the energy obtained from the casein, thus balancing the energy nitrogen ratio which in the presence of a suitable amount of the other bacterial nutrients, would result in the available nitrogen being assimilated, thus inhibiting ammonia accumulation. Consequently, by the time the dextrose was decomposed, there would not be time enough or a large enough number of bacteria present to give an impetus to ammonification sufficient to overcome the loss of ammonia consumed in the presence of dextrose.

In order to test these views, experiments were run, using media and flasks identical to those used above. Counts were made on the 2d, 4th and 6th days, along with the ammonia determinations.

The results in Table VII tend to confirm the theory that the stimulative effect of .05% dextrose upon the ammonification of casein was due to the increased number of bacteria in the dextrose casein medium and the consequent accelerated decomposition of casein after the dextrose was exhausted. While there is neither a wider difference in the numbers of bacteria in the two media at the beginning than there is at the close nor such a striking difference in stimulative effect upon *B. mycoides* and *Megatherium* as compared with the four remaining organisms, there is a relation between dextrose added, bacteria present and ammonia accumulated that is striking enough to allow ready interpretation.

An examination of the table will show that increasing quantities of dextrose show increasing numbers of bacteria. The rule holds fairly constant for each of the 48-96 and 144 hour periods. Within the limits of the experiment, the greater the amount of dextrose, the greater the increase in the number of bacteria.

If the influence of dextrose in increasing quantity upon the ammonia which accumulated is considered it will be found that this evidence tends to confirm the theory that the stimulative effect of .05% of dextrose upon the ammonification of casein was due to the action of the increased numbers of bacteria in the dextrose casein medium after the dextrose was exhausted. A comparison of column 2 with columns 4, 6 and 8 will show that .05%, .1% and .2% of dextrose decreased the amount of ammonia which had accumulated in the media in 48 hours. It will likewise show that the amount of ammonia in the medium was practically constant for each organism, regardless of the amount of dextrose added. Theoretically, there should have been less ammonia in the presence of .1% dextrose than with .05% dextrose and less with .2% than with .1% because of the higher bacterial count. Perhaps more accurate method of determining ammonia might give this result.

The explanation for the fairly uniform quantity of ammonia in the presence of varying quantities of dextrose is that after 48 hours there was still left sufficient dextrose from the .05%, as well as the .1% and .2%, so that the equilibrium between the ammonia formed

by the decomposition of the casein and that assimilated by the bacteria, using dextrose as a source of energy, was maintained at nearly the above concentration.

TABLE VII. THE INFLUENCE OF TIME UPON THE EFFECT OF INCREASING QUANTITIES OF DEXTROSE UPON THE AMMONIFICATION OF CASEIN AND THE INCREASE IN THE NUMBER OF BACTERIA

48 HOUR INCUBATION								
Organism	C.		C.+.05% D.		C.+.1% D.		C.+.2% D.	
	Mgm. NH ₃	M. B.	Mgm. NH ₃	M. B.	Mgm. NH ₃	M. B.	Mgm. NH ₃	M. B.
<i>B. subtilis</i>	15.7	2.9	13.	4.6	12.0	4.9	13.2	4.0
<i>B. proteus</i>	13.8	5.1	10.9	6.0	11.8	6.8	10.9	6.9
<i>B. mycoides</i>	22.6	4.7	14.8	4.4	13.9	3.8	14.0	4.8
<i>B. megatherium</i> ..	14.7	9.2	14.0	11.6	13.8	11.6	13.0	12.4
<i>B. vulgatus</i>	20.	11.4	16.0	16.2	15.7	16.0	15.8	17.5
<i>S. lutea</i>	12.9	1.9	11.2	2.0	11.9	2.8	10.8	3.1
96 HOUR INCUBATION								
<i>B. subtilis</i>	25.1	11.4	20.0	22.8	15.9	30.9	13.0	33.0
<i>B. proteus</i>	20.2	21.1	22.0	39.2	13.7	48.3	15.0	50.1
<i>B. mycoides</i>	64.0	25.9	20.1	32.1	14.4	33.0	15.0	37.0
<i>B. megatherium</i> ..	21.0	32.7	25.0	49.9	2.9	42.0	12.0	48.0
<i>B. vulgatus</i>	27.9	39.6	26.0	68.8	24.2	70.0	20.0	69.1
<i>S. lutea</i>	22.4	5.9	10.2	7.6	11.9	6.11	12.0	7.4
144 HOUR INCUBATION								
<i>B. subtilis</i>	49.5	49.0	55.0	54.7	48.7	54.3	17.0	59.0
<i>B. proteus</i>	30.3	86.6	32.	80.1	30.1	89.1	15.7	92.2
<i>B. mycoides</i>	69.6	63.2	60.	65.9	52.	66.7	11.9	66.1
<i>B. megatherium</i> ..	36.2	70.0	29.	78.1	27.4	77.	19.0	78.1
<i>B. vulgatus</i>	33.7	82.0	44.4	97.7	30.3	99.8	27.0	131.1
<i>S. lutea</i>	26.1	7.9	20.	19.0	11.3	10.7	11.0	8.9

The columns headed C. represent casein alone. The columns headed C+.% D represent casein + dextrose.

The sub columns headed Mgm. NH₃ represent the milligrams of ammonia.

The sub columns headed M. B. represent millions of bacteria per c.c.

Turning now to the 96 hour analysis, it is evident in every instance excepting *Sarcina lutea* that the depressing effect of .05% of dextrose upon ammonia accumulation has lessened markedly. In some instances it appears as though the effect of .1% dextrose is less effective than at 48 hours, although it is not decisive enough to be sure, particularly when one considers the effect of .2% dextrose which runs very similar to .1%.

If one now considers the 144 hour period, it will be observed that the depressing effect of .05% of dextrose upon ammonia accumulation has given place to a stimulative effect upon ammonia accumulation, coincident with the stimulative effect as noted in Table VI. There is, however, a difference between the two tables in the results of *Sarcina lutea*. In Table VII, .05% dextrose at 144 hours still seems to retard

ammonia accumulation with *Sarcina lutea*. An examination of the results recorded on *Sarcina lutea* will show throughout the course of the experiments that this organism grows rather erratically in the media employed here, thus indicating by its erratic growths and low counts that it handles casein with difficulty. On the other hand, it may be noted that *B. subtilis*, *B. proteus* and *B. vulgatus* shows the distinct stimulative effect of .05% dextrose, while *B. mycoides* and *B. megatherium* still shows the depressing effect of the .05% dextrose as well as with .1% and .2%. Therefore, within the limits of the experiment, a small quantity of dextrose first depresses and later stimulates ammonia accumulation from casein decomposition by *B. subtilis*, *B. proteus* and *B. vulgatus*. The depression of ammonia accumulation with these organisms is probably due to the fact that as long as dextrose is available, they assimilate the ammonia liberated from the casein. On the other hand, when the dextrose is exhausted early in the incubation period, there is a greater number of bacteria present to decompose the casein than there is in the casein medium. Consequently, there is a more rapid decomposition of casein with a more rapid accumulation of ammonia, so that with a six day period, the .05% dextrose casein medium contains more ammonia than the casein medium. Likewise, where the amount of dextrose added does not disappear until late in the incubation period, there is not sufficient time for the greater number of bacteria to liberate sufficient ammonia to more than make up for the amount of ammonia assimilated. Therefore, it will be seen that the marked depressing effect of .1% dextrose at 48 and 96 hours has not entirely been overcome at 144 hours. Whether it would be overcome by a little more time must remain for future determination. By proving that the acceleration of ammonification of casein in the presence of .05% dextrose is due to an increase in the number of bacteria, we have virtually added another proof of ammonia assimilation as the chief factor in depression of ammonification in the presence of dextrose.

The data presented in Table VII confirms the results of Lipman and associates, (Bul. 247, New Jersey Station, page 8). In the work of these investigators, it will be noted that the amount of ammonia liberated from dried blood alone at the end of five days, and that from dried blood and .5 gram dextrose was respectively 17.17 mgm. 15.26 mgm. at 6 days it was 32.53 and 30.80 respectively, at 7 days it was 44.07 and 37.25, while at 8 days it was 46.02 and 47.53 and on the ninth day it was 42.44 and 46.89. If .5 gram of dextrose did not increase the ammonification of dried blood in this instance, it, at least, did not depress it.

The concluding statement by the authors in discussing these results is as follows. "Here, as in series 2, the dextrose either has a depressing effect upon the yield of ammonia nitrogen, or its presence favors the development of those organisms which use ammonia; the latter view is more probable. It may be pointed out that while dextrose and other carbohydrates do seem to have a depressing effect on ammonification, still a point is finally reached beyond which depression is not great, that is: with relatively large amounts of dried blood, the depression is comparatively small."

THEORETICAL CONSIDERATION*

The data presented in Table I indicates with a fair degree of certainty that the six ammonifying organisms used in these experiments are able to assimilate ammonia when dextrose is present. This view is confirmed by the data presented in Tables III, IV and VII. The ability to assimilate ammonia in the presence of dextrose is perhaps the principal reason for the "depressing influence" of dextrose upon ammonification. This suggests: (1st), a more concise definition of the term "ammonification"; (2nd), a closer scrutiny of our methods of investigating ammonification in particular and physiological methods in general; (3rd), readjustment of the views of "beneficial" and "detrimental" soil saprophytes; (4th), the relation of the numbers of these beneficial bacteria to soluble plant food and soil fertility; (5th) the influence and relation of the "beneficial" bacteria to manures and fertilizers in and out of the soil; and (6th) a deeper seated, more fundamental problem, namely: the relation of energy supply to bacterial activity and the suitable adjustment of the energy supply for maximum available plant food production. If it is proven that these bacteria, long regarded as essential factors in the production of available nitrogen, may, with certain proportion of energy to nitrogen, become the consumers of that nitrogen which would otherwise be transformed to available plant food, and if it is shown that the energy supply is the limiting constituent of bacterial food, at least in many soils, then it is a problem of fundamental importance, the solution of which will yield important, practical results.

A study of the literature on ammonification reveals a striking indefiniteness in the use of the term. It would probably be fair to say that the use of the word "ammonification" as found in literature, is applied to the biochemical decomposition of nitrogenous matter that results in the nitrogen of the organic matter being liberated as ammonia. This carries with it the assumption that the nitrogen liberated may be obtained and measured by proper distillation for ammonium compounds. Likewise the impression left is that the ammonia thus liberated cannot be used by the ammonifying organisms. In other words, the ammonia from ammonification is an end product of the transformation requisite for the development of an organism, and, as far as the causative organism is concerned, will remain in the medium as ammonia, although it may be removed by other organisms. A further scrutiny of the subject of ammonification will reveal two factors that must be considered in defining ammonification. First: the act of liberating ammonia; second, the ammonia that accumulates within the medium and remains unchanged until determined. Are the two equal to each other when only ammonifying organisms are present? Literature upon the subject would indicate that the ammonia liberated, i. e., ammonification has always been measured by the amount which accumulates within the medium. In other words: if one accepts the definition that ammonification is the biochemical liberation of ammonia, and persist in measuring it by

*In taking up the theoretical discussion, the writer assumes other chemical and physical factors are favorable for the microorganisms development and an absence of any inhibitive agent.

the amount which accumulates within the medium, then one must determine whether the real and apparent ammonification are equal. If such is not the case, one must learn to measure those factors which cause a difference between the real and apparent ammonifying power.

One is now in a position to note whether the preceding data is in agreement with these views on ammonification.

In Table I it was observed that the six bacteria used in these experiments were able to assimilate ammonia in the presence of a suitable source of energy. These organisms are well known ammonifying bacteria. This fact strikes immediately at one of the theoretical factors of ammonification. If these organisms can assimilate as well as liberate ammonia, is there any proof that all the nitrogen from some or all ammonifiable materials may not have been liberated as ammonia. The bacteria then assimilate sufficient to balance the limiting factor in the bacterial ration.

The ammonia in excess of the organism's requirements may accumulate within the medium as the decomposition of the nitrogenous matter proceeds. The limiting bacterial food factor, in most instances, is probably the energy material. Under such conditions as were present in Tables II, III, VI and VII, where casein was the only organic matter present, may not the milligrams of ammonia given in those tables represent only part of the nitrogen liberated as ammonia by the respective organisms? This is not far fetched but based upon the results obtained with synthetic media containing nitrogen as ammonia only, and the results with ammonification of casein in the presence of dextrose. In the first instance, each of these organisms consumed ammonia. In the second instance, some of the ammonia liberated from the casein was apparently consumed by the organisms which liberated it, because there was present excess energy. What is more reasonable than to assume that under some conditions the decompositions of nitrogenous organic matter that results in the liberation of ammonia is brought about through the efforts of the organism to obtain energy? The natural conclusion is that the organism assimilates sufficient ammonia to balance the energy or some limiting nutrient element, leaving the remaining ammonia to accumulate within the medium.

It becomes apparent that an increase in the proportion of energy over nitrogen* should result in a decrease in the amount of ammonia left in the medium. A marked difference also exists between the real and apparent ammonifying power. Up to a certain degree, it becomes more diverged as the proportion of energy to nitrogen increases. Such, for example, as the ammonification of casein in Tables II, III, VI, and VII where dextrose was added.

For the sake of illustration, the difference between the real and apparent ammonifying powers of the strongest and weakest ammonifier shown in Table II may be used. *B. mycoides* liberated 72.8 mgm. of ammonia with casein and 3.6 where casein was used with dextrose, a decrease in its ammonifying power of 95%. *B. proteus* acting on casein alone had an ammonifying power of 15.2 mgm. With casein

*Assuming that all other necessary food constituents are present in sufficient quantity.

and dextrose, its ammonifying power was 3.6 mgm. a decrease of 76% in ammonifying power. It is, therefore, apparent that the difference between the real and apparent ammonifying power may be considerable, and will vary with the composition of the ammonifiable substance even in the absence of dextrose as illustrated in Table VIII.

According to the present view of plant nutrition, either ammonia or nitrate nitrogen may serve as plant food. In many instances, at least, the ammonia may either be assimilated direct or oxidized to nitrates. Consequently, the great desideratum in the decomposition of organic matter within a soil, appears to be not necessarily just the liberation of ammonia, but actually the accumulation of ammonia so that it may serve as plant food direct, or for oxidation to nitrates. The mere liberation of ammonia and its subsequent transformation to protein cell substances, either by the ammonifying organism or by other microorganisms, has no immediate value* as far as determining the ammonifying power is concerned, and should not be considered in defining ammonification. Therefore ammonification should be defined as that process in which the nitrogen; of the organic matter, that is in excess of the energy-nitrogen ratio of the ammonifying organism, is liberated as ammonia.

In order to clear the ground for future discussion on energy relations, one more view of ammonification as a natural phenomena will be considered. It will be recalled that the casein and casein dextrose were dissolved in a nutrient solution containing definite quantities of known compounds. These known compounds were, with certain exceptions, necessary for bacterial growth. Quantitative tests were made for phosphorous, magnesium and iron, at the end of the trials recorded in Tables II, III, VI and VII and show distinctly that there were more of these constituents unconsumed in the absence of dextrose than there were in the presence of dextrose. Furthermore, the amount of these constituents consumed were closely proportional to the amount of ammonia and dextrose consumed. There was, in every instances, less than 40% of the mineral constituents consumed. Therefore, in the presence of .2% or more of dextrose, nitrogen was the limiting bacterial food element. Limiting because, as previously pointed out, it was assimilated until the dilution was so great the bacteria could not obtain it fast enough to sustain the rate of growth. The rate of liberation and assimilation had reached an equilibrium, and in the presence of abundant energy material and nutrient constituents, the concentration of ammonia was held to the minimum concentration usable† by the bacteria under these conditions. Therefore, if ammonification brings about the liberation of the ammonia that is in excess of the energy-nitrogen ratio and that it results in the accumulation of the excess ammonia within a medium, then it is possible to understand and explain the phenomena of ammonification.

*The liberation and assimilation of ammonia does have a value in soil fertility, is pointed out on page 382.

†It is not meant to imply that these bacteria cannot utilize slowly a concentration of ammonia below the lowest amount recorded in these experiments.

TABLE VIII. RELATIVE AMMONIFICATION OF EGG ALBUMEN AT ROOM TEMPERATURE COMPARED WITH THE AMMONIFICATION OF CASEIN

Name of organism	Mgm. of NH_3 liberated	Relative ammonifying power with egg albumen	Relative ammonifying power with casein. Table II.
<i>B. subtilis</i>	25.8	5	3
<i>B. proteus</i>	55.5	2	6
<i>B. mycoides</i>	76.0	1	1
<i>B. megatherium</i>	23.1	6	5
<i>B. vulgatus</i>	49.7	3	4
<i>S. lutea</i>	37.9	4	2

Ammonification is due to an unbalanced bacterial medium, in which the nitrogen of the decomposing organic matter is in excess of the nitrogen requirements of the microorganism. Consequently, any organism which can decompose a nitrogenous substance, as far as the ammonia stage, will be an ammonifying organism if the nitrogen in the organic matter is in excess of the nitrogen requirements of the organism. And as a corollary to the above, if it is assumed that the relation of the other available plant food constituents have a relation to energy, similar to nitrogen, then as long as the readily forming energy material is in excess of the required ratio of energy to nutrients for any given soil flora, there will be an accumulation of available plant food near the minimum concentration required to sustain bacterial life. In most instances but one element will be present in small enough quantity to be held near the limit of concentration and plants will suffer by competition with microorganisms for the available plant food. The limiting elements, in order of their importance are probably nitrogen, phosphorous, potassium. When the energy material is below the ratio of energy to nutrients required for the soil's flora, there will be an accumulation of available plant food. Competition between plants and microorganisms will be nil, or at a minimum, and the decay microorganisms will exhibit only their "beneficial" attributes. However, according to the law of physics that the accomplishment of work requires an equivalent of energy for each unit of work performed, one would expect to find a gradual cessation of the activities of microorganisms if the energy material approaches exhaustion. Consequently it is to be expected that future investigations may reveal a proportion of energy to nutrients below which the accumulation (21) of available plant food will be retarded and finally practically cease.

This theory of ammonification may be illustrated by the hypothetical ammonification of amino-acetic acid. In the presence of suitable oxidizing agents, amino-acetic acid may be oxidized to CO_2 , H_2O and NO_3 . The heat of combustion is 210 calories. Assuming for the sake of illustration that no carbon for building of cell substance is necessary, and that an oxidation of a gram molecule of amino-acetic acid to CO_2 , H_2O and NH_3 may be brought about by an organism whose energy ratio to ammonia is equivalent to 210 calories of heat to 17 grams of NH_3 nitrogen. In round numbers the energy ratio to NH_3 expressed as calories to grams would be 12 to 1. Theoretically, there would, under this condition, be complete oxida-

tion of the amino-acetic acid and a complete assimilation of NH_3 . The reaction may be expressed as follows:

(1) 75 gm. $\text{CH}_2 \text{NH}_2 \text{COOH}$ + oxidizing enzyme + 48 gm. O = 88 gm. CO_2 + 18 gm. H_2O + 17 gm. NH_3 + 210 calories and

(2) 210 cal. + 17 gm. NH_3 + other nutrients = x bacteria.

In this instance there would be no ammonification because the energy nitrogen ratio was balanced. If the energy nitrogen ratio of the organism was 24 to 1, we might expect theoretically the results expressed in the following equation:

(1) 150 gm. $\text{CH}_2 \text{NH}_2 \text{COOH}$ + oxidizing enzyme + 96 gm. O = 176 gm. CO_2 + 36 gm. H_2O + 34 gm. NH_3 + 420 calories, and

(2) 420 calories + 34 gm. NH_3 + other nutrients = x Bacteria + 17 gm. NH_3 in excess.

In this instance the ammonification is represented by 17 grams of ammonia in excess* of the energy nitrogen ratio of the organism.

Again a complete decomposition of a nitrogenous compound with twice the amount of potential energy as amino-acetic, but the same amount of nitrogen would not result in ammonification in either instance, but in the first instance there would be opportunity for the assimilation of ammonia from other sources.

It is possible that we have here one of the factors that influence the so-called "physiological efficiency" of bacteria. In the presence of a source of energy suitable to the organism, the most efficient ammonifying** bacteria become relatively inefficient. If one observes the relative number of bacteria and their ammonifying powers on casein and again on casein in the presence of dextrose as in Tables III and VII there may be seen one of the reasons why the ammonifying power of a soil may be low while its bacterial numbers are high and vice versa.

Turning to the methods employed for determining the ammonifying power of soils, it may be expected, as shown in Tables II, III, VI and VII that a soil with a high available energy content*** of organic matter will be low in ammonifying power.

*If microorganisms responds to excess nitrogen in a manner similar to oats one might expect to find a high percentage of nitrogen in the bacterial cell where nitrogen was greatly in excess of the energy-nitrogen ratio.

**Unpublished notes on synthetic media (70) show that assimilation of ammonia is possible with practically every ammonifying bacteria tried.

***It would be misleading to say that soils with a high proportion of carbohydrates to nitrogen would have a low ammonifying power since my unpublished note on synthetic media, as well as numerous references show that other compounds than carbohydrates serve as a source of energy. Neither would it be correct to say the "carbon nitrogen ratio" because some soils with a high ratio of carbon to nitrogen are strong ammonifying soils and vice versa. Again, there are numerous soil compounds whose decomposition is so difficult that microorganisms find difficulty in obtaining energy by oxidation. These compounds may be illustrated by the saturated hydrocarbons and aromatic hydrocarbons. Such compounds form but a small percentage of organic matter but tend to accumulate within a soil until their slow disappearance just balances their accretions. Hence, a soil which for some time has received no addition of available energy may have a carbon nitrogen ratio similar to a strong ammonifying soil.

Unfortunately, enough is not known about the energy requirements of ammonifying bacteria to be able to detect by analysis the energy constituents of such soils. Nevertheless, by adding substances such as dextrose, it may be demonstrated that such is the case. See page (388). However, our purpose is to discuss the preceding data in relation to methods of determining the ammonifying power of soils.

At first it would appear that only under experimental condition could the energy, equivalent of the amount of dextrose used in these experiments, occur in soils. Such is not the case. In Table VI it may be noted that .2% dextrose caused a marked disappearance of ammonia. The dextrose content was .2% of a liquid culture. Now, if the average acre foot of soil weighs 3,000,000 pounds and has a water content of 25%, it will require .2% of 25% of $\frac{3,000,000}{2}$ pounds or 750 pounds of dextrose, or its energy equivalent to cause a like decrease of ammonia in a soil plowed six inches deep. Earlier test with casein and dextrose in sand, with pure cultures of bacteria, showed an even more marked decrease than in liquid media, in the presence of dextrose. Therefore, there need not be assumed to be a difference in the soil and solution. However, the .2% of dextrose in sand cultures began to lose its effect on the fourth day. Consequently one might expect to find a more rapid disappearance of the dextrose from a soil. Now, the stubble and roots of cereal crops added to a soil will frequently approximate this amount of energy in terms of dextrose. The same is true of green manures. Since in air dry materials, the nitrogen free portion of these substances range from 80 to 90%, one might expect some influence upon the ammonifying power of the soils, providing the cellulose of these materials may serve as a source of energy. On this point see page (389). As these substances do serve as a source of energy and as they are more complex and more difficult of decomposition. There may be expected not only a decrease in ammonifying power but also a longer continued decreasing effect. See page (389). If a soil's ammonifying power is tested for a certain period after having plowed under considerable organic matter, there will be found a distinct depression of ammonification provided the organic matter in the sample is not removed. If an aliquot portion of organic matter is not obtained there will not be secured a fair index of the ammonifying power.

This helps to explain why such marked differences are frequently found in checks in determining the ammonifying power of soils. One of the samples may have considerable more active organic matter present than the other. This also helps to explain the decreasing ammonifying power of soils after plowing, followed a few weeks later by an increase in ammonifying power. It may likewise be expected that a lessening of the ammonifying powers of a soil will take place after the application of large quantities of strawy manure.

There may now be taken up for consideration the relation of energy supply to bacterial activities and the relation of these physiological, activities to available plant food, these features can be pointed out in a concrete way by referring to the results in Table VII. It was for this purpose of studying the relation of bacterial activities to available plant food that the six test organisms used in these

experiments were selected. If it could be shown that well known ammonifying bacteria under suitable energy conditions would assimilate a high percentage of the ammonia produced by them, there would be a deeper significance attached than if it was proven that other organisms not so important in our theories of soil metabolism would assimilate ammonia nitrogen, since it has long been known that certain (so called detrimental) bacteria and molds assimilate ammonia and nitrate nitrogen, and under suitable conditions seriously compete with crops for the available nitrogen. Likewise too, reasoning by analogy, other plant food elements are probably assimilated in appreciable amounts by these same "beneficial" bacteria. If such a relation of energy to bacterial food ever obtains within a soil, the terms "beneficial" and "detrimental" bacteria would lose significance, and force the use of a more exact statement of the functions of these organisms.

It will be observed that in the media employed in these experiments, all the compounds used, excepting casein and dextrose, are known available forms of food for domestic plants. If ammonia is substituted for the casein, available plant food is identical to bacterial food with the exception of dextrose which may be utilized (60 and 61) by plants, but is not necessary for their growth. Therefore, aside from the energy requirements of the higher plants and microorganisms, their food elements are, in general, identical. The only remaining difference is that microorganisms have the property of transforming insoluble organic matter into soluble forms, certain of which may be assimilated by either the plants (62) or the microorganism. The microorganisms in transforming the insoluble nitrogenous organic matter to soluble form obtain a part of their energy from these reactions, for example: the decomposition of casein. Plants cannot, as far as known, transform insoluble organic matter into soluble form, but must have it supplied in soluble form*. This shows how the higher plants are dependent upon the microorganisms. The microorganisms must transform the organic debris into soluble forms and thus there is established the relation of bacterial activities to available plant food. Insofar as the theory goes, it is correct, but unfortunately, it leaves the impression that as soon as the plant food is made available, it is entirely at the disposal of the higher plants, excepting that portion which may be lost by leaching and that transformed chemically into insoluble forms like reverted phosphates, or the loss of nitrogen by denitrification or assimilation by "detrimental" microorganisms. Such is not the case. Plants and the so-called beneficial microorganisms compete for the soluble or available food elements. The competition does not become severe in the average soil unless the amount of plant food that may be readily converted into soluble form is small, or unless the energy supply for microorganisms is abundant. Under either of these conditions, the bacteria compete with the plants to such extent that a marked depreciation

*As pointed out in some recent work (62), the nitrogen does not even have to be in the form of ammonia or nitrates, but may be assimilated as amino acids and acid amides.

of yield results. This idea of competition between plants and microorganisms is of secondary importance, however, to the energy requirements of the microorganisms because a proper adjustment of the energy relations will mean a maximum development of microorganisms, followed later by a maximum concentration of available plant food.

It has been pointed out that the microorganisms must have energy at their disposal in order to transform the insoluble organic matter into soluble forms and that they obtain this energy by decomposing nitrogenous organic matter, or where conditions permit, by decomposing both the nitrogenous and non-nitrogenous materials. An excess of energy material caused the immediate assimilation of most of the ammonia liberated from the casein by the very organisms which liberated it. By analogy it may be seen how the other available plant food elements likewise may be assimilated.

Hence, one faces the problem of adjusting the energy relations of organisms at an optimum concentration, i. e., a proportion of energy material to nutrients which will give an optimum concentration and continued liberation of available plant food constituents.

Table VII gives a clue to the solution. It will be seen that .05% of dextrose caused, first, a distinct decrease, and later, an increase in certain instances in the amount of ammonia accumulated over that which accumulated with casein alone, while with .1% dextrose there was at first a distinct depression and later a recovery; in all but one instance, to within 3 to 14% of normal ammonia accumulation. Hence, in common parlance, the smaller quantity of dextrose lost its depressing effect sooner than the .1%. Looking at it from the point of view previously presented, the .05% dextrose was consumed before the .1%. Consequently, the consumption of NH_3 ceased before it did with .1%. In every instance there was a greater accumulation of NH_3 in the presence of .05% dextrose than with .1% dextrose and more with .1% than with .2%. When appreciable amount of dextrose remained in the medium there was no ammonia accumulation. As long as there remains an excess of easily decomposed energy forming matter in a soil in excess of the ratio of energy to nitrogen for the microbial flora of the soil, there will be no appreciable accumulation of ammonia. Since it is impracticable to suggest an adjustment of the energy nutrient ratio of the total organic crop remains added to the soil solution may be pointed out in another way by suggesting the correct time for incorporating into the soil the organic matter low in nitrogen. It has been pointed out (31) that a constant liberation of CO_2 from the soil takes place and that this liberation of CO_2 increases upon the addition of carbohydrates (31 and 13). Indeed, it has been suggested that the rate of liberation of CO_2 is in proportion to bacterial activities and might be used as an index for the same. The liberation of the CO_2 presages either the destruction of the nitrogen free substances or the carbon radicle of the nitrogenous matter paralleling the decompositions of casein and of casein and dextrose.

Therefore, as suggested by the results in table VII if the decomposition of the organic matter of the soil is given sufficient time, there will be narrowing of the energy nutrient ratio of the soil organic matter and an ultimate liberation of more abundant plant food not necessarily an immediate increase in ammonia or other nutrients, since in the soil the destruction of the energy material and assimilation of ammonia and other plant food constituents result in the formation of great numbers of microorganisms before the excess energy of added organic matter was consumed. Consequently, after the exhaustion of the energy material, large numbers of microorganisms die and may be regarded as an equivalent of the original organic matter with greatly decreased energy nutrient ratio. These cells in turn undergo decomposition. The ratio of energy to nutrients determined for any organism or flora must include that actually used by the synthetic actions of metabolism, and that which escapes into the surrounding medium as heat*. That is the potential energy stored in the cell of the microorganism is only a portion of that liberated originally by the organisms from the organic matter. The succeeding generations of organisms have at their disposal the energy material of the lower compounds resulting from the earlier decomposition, the dead cells of the previous generation and the compounds more difficult of decomposition which were in the original organic residue. Therefore, owing to the narrower ratio of energy to nutrient and to the energy compounds more difficult of decomposition, there is an increasing accumulation of soluble plant food that the microorganisms do not rapidly assimilate. This may be utilized as plant food, leached away, chemically changed, nitrified (21 and 22) or dentrified.

EXPERIMENT ON COMPETITION

In order to test the theory of competition between higher plants and "beneficial" bacteria, the following experiments were planned:

Maize seedlings free from microorganisms were grown in flasks and large tubes which contained pure quartz sand and sufficient synthetic nutrient solution to bring the water content of the sand up to 12%. Enough checks were run so that flasks and tubes contaminated at the end of the experiment could be eliminated. In the first series of experiments, the nutrient solutions containing dextrose were concentrated and the presence of bacteria stimulated the growth of the maize. For the second and third series of tests, media No. 1 was diluted 10 times and will be known as Medium No. 1-A. In the second series of experiments it was noticed that injury to the maize seedlings resulted from handling the seedlings with forceps sterilized in HgCl_2 . In the third series of experiments, this difficulty was overcome. The experiments in detail were as follows:

The first and most difficult item was to secure maize seedlings free from microorganisms. Fortunately an ear of flint corn was

*Such, for example, as the heat liberated in the rapid vinegar process and also the heat of fermenting manure.

secured which germinated approximately 100%; 200 kernels were removed from this ear and placed in a sterile vacuum flask. To the flask was then added 200 c. c. of the following disinfectant:

HgCl ₂	2 gm.
NH ₄ Cl	20 gm.
NaCl	10 gm.
Dist. H ₂ O	1000 c.c.

The vacuum flask was then connected and a vacuum of 20 to 25 pounds maintained for 30 minutes; the disinfectant was carefully drained off after which each kernel was transferred by means of sterile forceps to a tube containing 10 c. c. of nutrient bouillon. At the end of 48 hours, each kernel was transferred to an agar slope where it remained until the seedling was about 6-7 cm. long. Then by means of sterile forceps each seedling was transferred to 10 c. c. of nutrient bouillon where it remained for 72 hours. Then by means of long sterile forceps the seedling was planted.

The object in transferring the treated kernels from the disinfecting flask to the bouillon was to wash off and dilute the disinfectant remaining on the seed. No growths were noticed in the bouillon. The object in transferring the kernels from the bouillon to the agar slopes was to afford complete aeration. 40 seedlings out of the 200 were discarded because they were small or deformed. 12 out of the remaining 160 were contaminated with molds. After transferring the seedlings from the agar to bouillon, four more developed molds, and one tube developed bacterial growth.

The following media were used: Medium No. 1-A and the same medium without dextrose, which is designated Medium No. 1-B.

The apparatus used was as follows: 2 kilograms of quartz sand was added to wide mouthed, 2 liter flasks. Sufficient media (AorB) was added to bring the water content of the sand up to 12%. These flasks were then plugged with cotton and sterilized in the autoclav at 10 pounds for thirty minutes.

Glass tubing 40 mm. inside diameter and one meter long were plugged with cotton in both ends. A string was tied to one of the cotton plugs and led through the tube past the other plug extending about 6 inches past the end of the tube. Around the outside of the glass tube, on the end having the cotton plug with the string attached, was wrapped cotton so that the entire tube, and cotton would just fit inside the mouth of the 2 liter flask. These tubes were then sterilized in the autoclav at 15 pounds for 30 minutes.

The planting of the maize was accomplished as follows: Steam was generated from water in a pan 18x28 inches. Across this pan was placed a support for the 2 liter flask while planting. After the steam was flowing freely around the flask so as to carry chance organisms away from the mouth, the plug was removed from the two liter flask and two large holes bored in the sand within by means of a sterile spatula. Then by means of a pair of long sterile* forceps a maize seedling was carefully removed from the bouillon tube while it was held within the flowing steam and the seedling planted in one of the holes in the sand inside the 2 liter flask. A second seedling was

*It was these forceps sterilized to the above HgCl₂ that injured the seedlings.

planted in the same way. One of the sterile, double plugged, 40 mm. by 1 meter, glass tubes was then taken from the autoclav and the cotton wrapped end inserted as a plug, within the mouth of the 2 liter

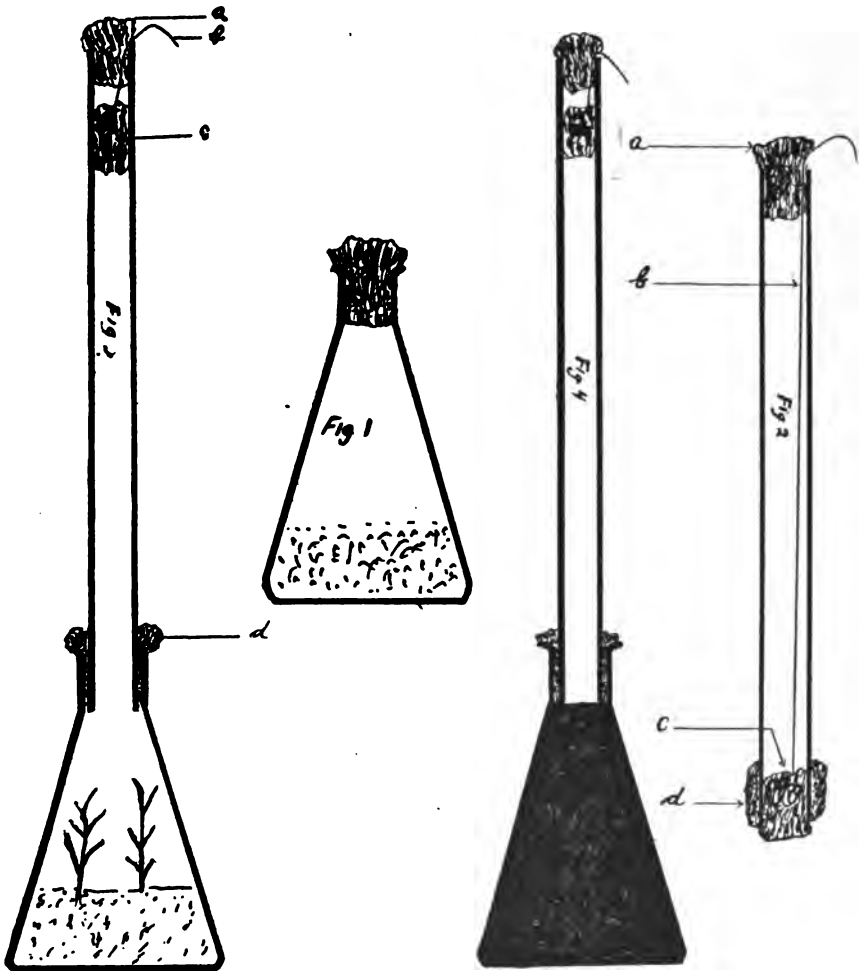


PLATE I

Fig. 1 Flask with sand and medium after sterilization.

Fig. 2 Forty mm. by one meter pipe after sterilization.

a—Top plug

b—Cord

c—Bottom removable plug

d—Cotton collar to fit in d Fig.

3

Fig. 3 After planting.

a—Top plug

b—Cord

c—Bottom plug

d—Collar

Fig. 4 After planting, enclosed in tar paper.

TABLE IX. SHOWING THE RESULTS OF COMPETITION BETWEEN MAIZE AND AMMONIFYING BACTERIA IN SYNTHETIC SOLUTION WITH DEXTROSE PRESENT AND ABSENT. TIME OF GROWTH: 7 WEEKS

Bacteria Present	No. of flasks in test	No. of plants in test	Treatment	Grams dry wt. in each flask	Average wt. of plants per flask gm	Total dry wt. gm	Wt. calculated for 8 plants per flask gm
B. subtilis	4	8	Media No. 1-A-dextrose 5 c.c. 72 hr. culture	2.7 2.0 1.9			
No. bacteria	4	8	Media No. 1-A-dextrose	1. 2.0 1.2 1.	1.9	7.6	7.6
B. subtilis	3	6	Media 1-A 5 c.c. 72 hr. culture	2.1 1.0 0.9 1.1 2.2	1.8	7.3	7.3
No. bacteria	4	8	Media 1-A	1.9 1.6 1.8	1.0	3.	4.0
B. proteus	4	8	Media 1-A-dextrose 5 c.c. 72 hr. culture	2.0 1.8 2.9 2.2	1.8	7.5	7.5
No. bacteria	3*	6	Media 1-A dextrose	2.1 2.6 2.8	2.2	8.9	8.9
B. proteus	4	8	Media 1-A 5 c.c. 72 hr. culture	1.4 1.6 1.1 1.9	2.5	7.5	10.0
No. bacteria	4	8	Media	2.1 2.2 1.8 1.7	1.5	6.0	6.0
B. mycoides	4	8	Media 1-A-dextrose 5 c.c. 72 hr. culture	3.0 2.2 1.6 1.9	1.7	7.9	7.9
No. bacteria	4	8	Media 1-A-dextrose	1.6 2.9 2.2 2.3	2.1	8.7	8.7
B. mycoides	4	8	Media 1-A 5 c.c. 72 hr. culture	1.0 .9 .8 1.1	2.2	9.0	9.0
No. bacteria	4	8	Media 1-A	2.8 2.3 1.7 1.9	.9	2.8	3.8
B. megatherium	4	8	Media 1-A-dextrose 5 c.c. 72 hr. culture	2.8 2.1 1.8 1.6	2.1	8.7	8.7
No. bacteria	4	8	Media 1-A-dextrose	2.2 2.6 2.3 2.0	2.0	8.3	8.3
B. megatherium	3*	6	Media 1-A 5 c.c. 72 hr. culture	.8 1.3 1.7	2.2	9.1	9.1
					1.2	3.8	5.0

*One or more flasks eliminated because of mold contamination. There was no bacterial contamination. Six flasks in all were eliminated because of contamination. Although provision for watering had been made, it was not found necessary. The three-foot tube with cotton plug acted as a reflex condenser sufficiently to retain sufficient water for growth.

(Continued on next page)

TABLE IX—(Continued)

Bacteria Present	No. of flasks in test	No. of plants in test	Treatment	Grams dry wt. in each flask	Average wt. of plants per flask gm	Total dry wt. gm	Wt. calculated for 8 plants per flask gm
No. bacteria	3*	6	Media 1-A	2.7 2.5 1.0	2.0	6.2	8.2
<i>B. vulgatus</i>	3*	6	Media 1-A-dextrose 5 c.c. 72 hr. culture	2.5 1.5 3.2	2.4	7.2	9.6
No. bacteria	4	8	Media 1-A-dextrose	2.8 2.7 3.1 2.3	2.7	10.8	10.8
<i>B. vulgatus</i>	4	8	Media 1-A 5 c.c. 72 hr. culture	.7 .9 .8 1.0	.8	3.4	.8
No. bacteria	4	8	Media 1-A	3.0 2.7 2.5 2.8	2.7	11.0	11.0
<i>S. lutea</i>	3*	6	Media 1-A-dextrose 5 c.c. 72 hr. culture	1.1 3.0 4.0	2.7	8.1	10.8
No. bacteria	4	8	Media 1-A-dex-	2.7 2.1 2.5 2.9	2.5	10.2	10.2
<i>S. lutea</i>	4	8	Media 1-A 5 c.c. 72 hr. culture	1.8 1.7 2.0 1.3	1.7	6.8	6.8
No. bacteria	4	8	Media 1-A	3.0 2.0 3.3 1.3	2.4	9.6	9.6
No. bacteria	4	8	Sand only and distilled water	.9 .5 .7 1.1	.8	3.2	3.2
Mixed culture of bacteria ..	4	8	Sand 5 c.c. mixed cult. of above bact. and distilled water	1.1 .9 1.2 1.3	1.0	4.2	4.2

*One or more flasks eliminated because of mold contamination. There was no bacterial contamination. Six flasks in all were eliminated because of contamination. Although provision for watering had been made, it was not found necessary. The three-foot tube with cotton plug acted as a reflex condenser sufficiently to retain sufficient water for growth.

erlenmeyer flask. The string attached to the lower cotton plug of the long glass tube was drawn up until the bottom plug almost touched the upper plug. Tar paper was then wrapped closely around the erlenmeyer flask so as to shut out the light and force the maize seedlings to enter the 40 mm. tube which they did. The entire apparatus was placed in the greenhouse. At the end of the experiment all contaminated flasks were eliminated. Those flasks to which were added bacteria were inoculated immediately after the maize was planted. The results and treatment are given in Table IX.

An examination of Table IX will demonstrate clearly that within the limits of this experiment that a medium containing dextrose, and with ammonia as the sole source of nitrogen, the ammonifying bacteria used in these experiments are able to successfully compete

with maize plants for the ammonia. It also points out that .001 gram of dextrose per c.c. does not stimulate the growth of maize plants. neither does it markedly depress it. The difference between the growth of maize in the absence of dextrose and in its presence lies within the difference due to individual plants. These points are clearly shown in Table X which is a composite of the total weights of maize plants presented in Table IX. The results in the two tables is a further demonstration of the influence of energy material on the activity of bacteria.

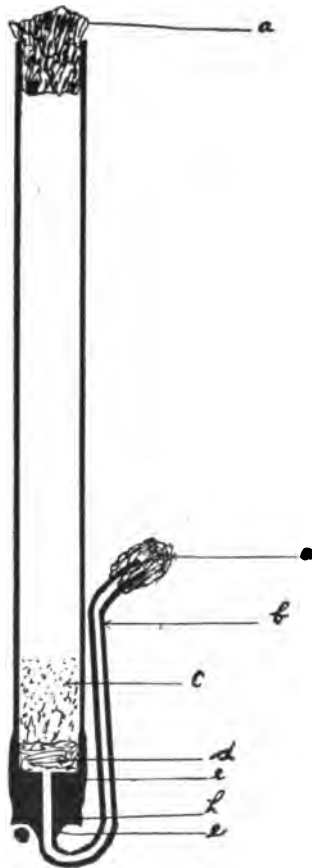


PLATE II

a—Cotton plug
b—Aeration tube
c—Quartz sand

d—Glass wool
e—Paraffin seal
h—Cork stopper

TABLE X. A COMPARISON OF THE TOTAL DRY WEIGHT OF AN EQUAL NUMBER OF PLANTS GROWN IN AN AMMONIUM MEDIUM, WITHOUT DEXTROSE, WITHOUT DEXTROSE AND BACTERIA, AND WITH DEXTROSE, AND WITH DEXTROSE AND BACTERIA

No. of Plants	Grams of dry weight in absence of dextrose and bacteria	Grams of dry weight in absence of dextrose with bacteria present	Grams of dry weight with dextrose present and bacteria absent	Grams of dry weight with dextrose and bacteria present	Controls sand only with distilled water to 12%
23	53.9				
22		48.8			
23			50.9		
22				26.8	
16					7.4
Corrected for 22 plants	51.4	48.8	48.4	26.8	10.6

As mentioned previously, some of the maize seedlings were injured by the $HgCl_2$ used to sterilize the forceps for transferring the seedlings from the agar slopes to the test apparatus. In order to eliminate this source of error the procedure for the third series was as follows:

The media and material used were the same as in the preceding test. The apparatus consists of a glass tube 40 mm. diameter by 1 meter; see Plate II, containing 500 grams of pure quartz sand. The maize kernels were sterilized in vacuo with disinfectant described above. After the sand had been added to the tube it was shaken until the surface of the sand lay sloped like an agar slant. The media was then carefully added while the tube lay in an inclined position. These tubes were then sterilized in an inclined position in the autoclav at 10 pounds for 30 minutes. After cooling, the tube was laid in a horizontal position, the plug was removed and one maize kernel transferred from the vacuum* sterilization flask to the culture tube. The tube was carefully lifted to a perpendicular position. The kernels then found a position at the lowest point of the sand slope. The tube was then rolled and jarred until kernels were covered by the crumbling of the sand slope. It was very noticeable that germination was slower in the presence of dextrose than in its absence. After the kernels were approximately 6 cm. high inoculations were made with a mixed culture of the six organisms used in the previous experiments. This method eliminated the injury due to handling with $HgCl_2$. There was no chance to select uniform seedlings, and the growth was not vigorous as in the previous experiments. The treatment and result are shown in Table XI.

The results in Table XI corroborated those in Table X in regard to the effect of competition between higher plants and beneficial bacteria when a suitable source of energy is present for the bacteria.

B. megatherium which had previously proven itself able to consume nitrate nitrogen in the presence of dextrose was tested out on a medium identical to No. 1-A, excepting that 1 gram of KNO_3

*20 to 25 pounds vacuum for 30 minutes.

TABLE XI. SEVEN WEEKS GROWTH OF MAIZE IN SYNTHETIC SOLUTION CONTAINING AMMONIA NITROGEN COMPARED WITH GROWTH IN THE SAME MEDIUM WITH DEXTROSE

Inoculation	Number of tubes in test	Number of plants in test	Medium used	Total dry weight gm.	Total dry weight calculated for 8 plants gm.
No bacteria	7*	7	Sufficient of Medium 1-A in pure quartz sand to give 12% moisture	7.9	8.9
5 c.c. of a mixed culture of 72 hr. growth of above 6 organisms	6*	6	"	2.5	3.2
No bacteria	8	8	Medium 1-A-dextrose in quartz sand to give 12% moisture	10.2	10.2
5 c.c. of a mixed culture of 72 hr. growth of 6 bacteria	8	8	"	9.4	9.4
No bacteria	7*	7	Quartz sand 12% distilled water	2.4	2.7
5 c.c. of a mixed culture of 72 hr. growth of 6 bacteria	5*	5	Quartz sand 12% distilled water	2.2	3.4

* One or more tubes eliminated at the close of the experiment because of contamination.

was substituted for the 1 gram of $(\text{NH}_4)_2\text{SO}_4$, which after dilution ten times was designated medium 1-BX. Likewise, *B. mycoides* was tested out on one tenth concentration casein dextrose medium 2-AX. The manner of conducting the experiments was the same as described for the results in Table XI. The growth period covered 9 weeks. Results are recorded in Table XII.

In Table XII may be seen the same relation between energy supply and nitrate consumption. *B. megatherium*, which can utilize NO_3 nitrogen and dextrose as a source of energy is capable of cutting down the growth of maize almost 50% under the conditions of the experiment. A similar relation holds between *B. mycoides* and casein and casein and dextrose as noted previously. Obviously, *B. mycoides* can deprive maize seedlings of considerable NH_3 , if there is present suitable energy material.

It has been proven by the previous results presented that six well known ammonifying bacteria in the presence of a suitable energy supply can successfully assimilate ammonia from $(\text{NH}_4)_2\text{SO}_4$, and can assimilate ammonia liberated from casein. This ability to assimilate ammonia has been further demonstrated by forcing maize under controlled conditions to compete with these bacteria for nitrogen. It has likewise been demonstrated that *B. megatherium* competes successfully with maize for NO_3 nitrogen, if suitable energy material is present. Furthermore, other bacteria and, in particular,

TABLE XII. 9 WEEKS OF GROWTH OF MAIZE ON POTASSIUM NITRATE AND POTASSIUM NITRATE AND DEXTROSE, ALSO *B. MYCOIDES* ON CASEIN, AND CASEIN AND DEXTROSE

Inoculation	No. of tubes used	No. of plants in test	Medium used	Average dry wt. in tube	Total weight gm.	Total weight corrected for 8 plants gm.
No bacteria	4	8	Medium 1-BX	3.1	12.4	12.4
5 c.c. 72 hr. culture of <i>B. megatherium</i>	4	8	Medium 1-BX	1.7	6.8	6.8
No bacteria	4	8	Medium 1-BX-dextrose	3.7	14.8	14.8
5 c.c. 72 hr. culture of <i>B. megatherium</i>	3*	6	Medium 1-BX-dextrose	3.9	11.7	15.6
No bacteria	4	8	Medium 2-AX-dextrose	1.8	7.2	7.2
5 c.c. 72 hr. culture of <i>B. mycoides</i>	4	8	Medium 2-AX-dextrose	2.7	10.8	10.8
No bacteria	3*	4	Medium 2-AX	0.8	2.4	3.2
5 c.c. 72 hr. culture of <i>B. mycoides</i>	4	8	Medium 2-AX	1.5	6.0	6.0

* One or more flasks eliminated at end of experiment because of contamination.

molds* readily use nitrate nitrogen (4) Tottingham and Hoffman (40) have demonstrated that under certain conditions bacteria consume the water soluble phosphates from ground rock phosphate and super phosphates. In order to demonstrate in a broader way that the energy material is the most important factor in bacterial food, a series of pot experiments were outlined and run under green-house conditions. It was the purpose of these pot tests to show that the same relation between energy and other bacterial nutrients holds with a complex flora as with the pure cultures previously used. Likewise, it was desired to point out the relation between bacterial food and plant food and bacterial activities and available plant food.

For this purpose, large flower pots holding 40 pounds of quartz sand were used. In order to guard against denitrification a coarse sand** was chosen which had approximately the following physical composition:

Gravel (less than 4 mm.....)	30%
C. S.	37%
M. S.	15%
F. S.	11
V. F. S.	6

The chemicals used were Merk's blue label with the exception of AlCl_3 , CaSO_4 , and casein which were Merk's highest purity. The nutrient ration per pot was as follows:

*Experiments similar to the above were conducted using different species of *Aspergillus* and *Penicillium*, but in the presence of dextrose these organisms were capable of killing the corn plant in from 3 to 6 weeks.

**Owing to the large amount of sand used it was not practicable to secure pure quartz sand.

$\text{Ca}(\text{H}_2\text{PO}_4)_2$	=	5.995 gm.
MgSO_4	=	2.150 gm.
NaCl	=	4.050 gm.
FeCl_3	=	.250 gm.
Nitrogen as KNO_3	=	8.725 gm.
or Nitrogen as $(\text{NH}_4)_2\text{SO}_4$	=	5.310 gm.
or Nitrogen as casein	=	8.340 gm.
MnSO_4	=	.005 gm.
AlCl_3	=	.005 gm.

All chemicals excepting FeCl_3 , MnSO_4 and AlCl_3 were added in a powdered form and thoroly worked into the sand by hand before the sand was added to the pot. The remaining chemicals were added from solution and mixed with the sand.

When 5.3 grams of $(\text{NH}_4)_2\text{SO}_4$ was substituted for the 8.72 grams of KNO_3 , then 7.82 grams of KH_2PO_4 was substituted for 5.99 grams $\text{Ca}(\text{H}_2\text{PO}_4)_2$ and 4.4 grams of $\text{CaSO}_4 + 2 \text{H}_2\text{O}$ was added to replace the calcium. This procedure was observed in replacing the 8.72 grams of KNO_3 with equivalent quantities of nitrogen in casein and manure, etc. The water content was maintained at approximately 12%, using distilled water. At the time of planting, 10 c.c. of a 1 to 5 soil infusion was added to each pot.

For convenience in discussion the first set of pots may be regarded as consisting of two series. The results for the first series, recorded in Table XIII, consist of checks. The second series consists of comparisons, using increasing quantities of ammonium sulphate with and without dextrose. See Table XIV.

Oats were used as a test crop. Preliminary work showed that pot work did not give comparable results unless a uniform number of plants were present in each pot. Effort was also made to force registration of the loss, due to bacterial competition, as decreased yield of the check crop. Consequently fifty kernels of oats were planted in each pot, and at the two leaf stage were thinned to 30 plants each. The striking results obtained encouraged an extension to include nitrate nitrogen and phosphates. The same plan and material were used as in the preceding tests, excepting millet was used as a test crop. Millet was chosen because it will grow readily in an acid soil (46). It was thought that the decomposition of large quantities of dextrose might seriously affect the soil reaction. Owing to the similarity of treatment and results, discussion of Tables XII and XIII will be taken up with the later trials.

The millet was planted February 1st and was uniformly up February 8th. February 15th, about half in some of the pots containing dextrose was dead. Plate tests showed numerous colonies of molds. (The identity of the parasite was not determined).

On the 25th of February all the millet was dead in some of the dextrose pots and most of it in others. Those pots having no dextrose and those having straw were not visibly affected. The presence of dextrose probably furnished energy for the parasites, enabling them to spread throughout the potted soil.

On March 1st the millet that remained was approximately 8 cm. tall. It was pulled and dried for nitrogen determination. That same day 50 kernels of Swedish Select oats were planted in each pot. These oats had won the sweepstakes prize at the North Dakota Pure

Seed Show for 1914 and germinated about 99%. They were plump, heavy seed. On March 5th, the oat plants in all of the pots were up with remarkable uniformity. On March 10th, the oats on all pots stood about 10 cm. high. On this date the plants were thinned to a uniform number. A preliminary investigation showed that one pot contained only 30 plants, one of which was weakly. This plant was removed. All other pots were thinned to 29 plants each. The pots, excepting those containing straw and fresh manure, continued uniform in growth and on March 20 examination showed that all dextrose had disappeared. Due to the porous, sandy soil, constant optimum moisture content and uniform temperature—automatically regulated to approximately 80°F.—the dextrose was rapidly decomposed. The finely chopped straw added to some of the pots showed considerable disintegration. On March 21st, dextrose was again added to the proper pots in the same quantities as in first application. Within 10 days sharp differences were noted between the several treatments. In no instance, however, did any of the oats show evidence of disease, except after heading when four pots contained from 1 to 2 smut heads. The differences noted were found in the pots containing dextrose with limited supplies of nitrogen or phosphorus. Where dextrose was used with an excess of all plant food constituents, no difference was visible to the eye. Nevertheless, the final yields showed some difference. The plants continuing to grow rapidly in all pots free from dextrose, straw or fresh manure and in those having dextrose and an excess of plant food. In those pots having a deficiency of one element and to which had been added either dextrose or straw or to which was added dextrose or straw only, apparently stood still, or became spindly. All plants remained healthy and green, even after the second application of dextrose. Where a limited amount of nitrogen or phosphorus had been used the tips of the leaves and the lower leaves became distinctly "fired", much as in cereals and particularly corn during a drouth.

Qualitative tests for dextrose demonstrated that the second application had disappeared by April 24th. About 20 days later there was a slight though distinct recovering noticeable in all the pots which had previously contained dextrose. A little later those pots to which straw had been added began to improve, while those pots to which fresh manure had been added did not begin to recover until about the middle of May. This recovery was manifested quite uniformly in two ways. First, the original culms began to elongate. Second: new growths appeared at the first and second nodes nearest the soil and grew rapidly. In many instances the green weight of the second growth appeared to be nearly equal to the green weight of the original stem, but the dry weight approximated only 20 to 30 per cent of it. Had the oats been harvested at the time the second application of dextrose disappeared, there is no question but that the difference in weight between the various treatments would have been more marked than shown in Tables XIII to XVII. Such results, however, would have emphasized only the competition between the oats and microorganisms and would not have suggested the true significance of energy material.

An attempt was made to obtain a quantitative estimate of the number of molds present in the pots to supplement the bacterial count. The chief difficulty was to secure an aliquot for transferring to the plate. A quantitative count of molds comes back primarily to an estimation of the conidia or other reproductive bodies present in the material under study. Owing to the fact that the conidia of some molds commonly floats upon the surface of water, cluster together and cling to the sides of the retaining vessel, the bacterial dilution methods fail to give uniform checks. Such checks frequently vary as much as 75%. The same conditions prevent estimation by a microscopic method. Some success was attained by adding minute quantities of soil to 10 c.c. of water, shaking, then transferring the entire volume of water and of soil to large plates. The dilution tube was twice rinsed with 10 c.c. portions of sterile water and both washings transferred to the plate. To this was then added 100 c.c. of synthetic medium containing 2% agar. The results do not justify presentation here since the synthetic medium used, permitted only *aspergillus* and *penicillium* to develop. The counts of these two genera alone ran into hundreds of thousands per gram of sand.

Ten days after the first addition of dextrose, qualitative microscopic estimates of the molds in the sand showed for the pots containing dextrose an enormous number of conidia. One platinum loop of suspension made by shaking 10 grams of the sand in 20 c.c. of water showed under the microscope a field so thick with conidia and bacteria of various species as to make counting at that dilution impossible. The conidia appeared to outnumber the bacteria many times. The conidia were abundant at 17 days and did not appear to decrease even at 45 days. A suspension made about 48 hours after the second application of dextrose showed a marked decrease in the number of conidia. This was followed a week later by an increase in number which equalled or exceeded those present after the first dextrose application. The number appeared to decrease toward the end of the experiment.

The presence of conidia in the pots treated with straw and fresh manure could be readily determined, though they were not as numerous as where dextrose was used. They persisted quite uniformly up to the end of the experiment.

The presence of molds in great numbers where energy material was present and the knowledge that these organisms readily consume both ammonia and nitrate helps to explain the exceptional depression of yield shown in Tables XIII to XVII. Although the qualitative data on molds does not permit detailed discussion of the effect of these microorganisms upon depression of crop yield, it suggests, in no small way, a probable influence of these organisms upon soil metabolism not hitherto fully realized. This influence is not necessarily detrimental as implied by their association with available plant food consumption and depression of crop yield, but a favorable influence equal may be, at times, to that of decay bacteria, as has been suggested by the work of Muntz and Coudon (47), Marchal (48), and recently by McLean & Wilson (17). That these organisms are quite generally present in agricultural soils has been demonstrated by the

TABLE XIII. YIELD OF OATS AND THE NUMBER OF BACTERIA DUE TO DIFFERENT TREATMENTS

Pot No.	Treatment ‡	Total dry weight gm.	Difference due to treatment	Av. loss due to dext.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
1	No treatment	13.9	0	0	.3	1.6	.9	.8	.6	1.2	.7	.8
2	No treatment	14.3	0	0	.3	1.1	.8	.8	.6	.9	.9	.7
3	10 c.c. soil infusion	14.0	0	..	.3	1.7	1.6	1.1	.6	.7	.6	.8
4	"	14.3	0	0	.3	1.0	1.3	.8	.9	.7	.5	.7
5	1 gm.* dext.	15.	+1		.3	8.6	3.1	2.2	6.2	5.3	3.3	2.8
6	"	16.	+2		.3	9.0	3.6	3.1	7.4	4.4	4.9	3.0
7	5 gm. dext.	14.	0	0	.3	9.5	7.7	3.3	9.9	6.4	4.4	2.5
8	"	14.	0	0	.3	9.0	5.8	3.5	11.2	6.1	3.8	1.9
9	30 gm. dext.	9.	-5	5	.3	9.7	7.5	6.5	10.8	10.3	7.8	5.2
10	"	9.	-5	5	.3	9.3	8.1	5.3	9.9	9.6	8.4	5.0
11	All nutrients except (NH ₄) ₂ SO ₄	15.	+1	0	.3	4.5	2.0	.5	.4	.7	.2	.4
12	"	14.	0	0	.3	3.1	1.3	.8	1.3	1.5	.8	1.0
13	All nutrients except KNO ₃	16.	+2	0	.3	3.3	2.3	1.8	1.0	.4	.5	.4
14	"	15.	+1	0	.3	4.0	3.1	1.9	.9	1.1	.8	.7
15	All nutrients except Ca(H ₂ PO ₄) ₂	15.	+1	0	.3	2.1	1.1	1.0	1.3	.7	.7	.8
16	"	14.	+0	0	.3	1.9	1.0	1.0	.9	.5	.3	.2
17	Full nutrient ration with (NH ₄) ₂ SO ₄ nitrogen	51.	+37	0	.3	4.4	1.7	1.7	1.0	2.0	.4	.5
18	"	49.	+35	0	.3	5.0	2.6	.9	1.3	1.7	1.2	.8
19	Full nutrient ration with nitrate nitrogen	48.	+34	0	.3	2.9	1.2	.6	.5	.9	.6	1.0
20	"	51.	+37	0	.3	3.7	1.0	1.4	1.1	1.3	1.8	1.5
21	Full nutrient ration with phosphorus	56.	+42	0	.3	3.3	.9	1.4	1.1	1.5	1.2	.8
22	Phosphorus series using nitrate nitrogen	52.	+38	0	.3	3.8	1.6	1.2	1.0	1.0	.9	1.3
23	All nutrients except (NH ₄) ₂ SO ₄ + 30 g. dextrose	8.	+6	6	.3	9.9	6.8	4.6	6.3	6.6	2.0	1.5
24	"	9.	-5	5	.3	10.2	7.5	5.3	5.9	5.3	2.8	1.7
25	All nutrients except HNO ₃ + 30 grms. dextrose	8.	-6	6	.3	10.3	4.1	5.2	7.0	5.8	3.2	1.5
26	"	8.	-6	6	.3	9.7	6.7	4.9	6.5	5.3	2.6	2.4
27	All nutrients except Ca(H ₂ PO ₄) ₂ + 30 grms. dext.	9.	-5	5	.3	8.3	5.4	3.2	4.0	3.9	3.3	1.0
28	"	10.	-4	4	.3	9.1	5.0	3.8	5.2	4.0	2.5	1.8

‡ Full Nutrient Ration—See Page 364.

* Large number of molds on plates from dextrose treated pots, a few on plates from pots treated with straw and manure. Occasionally one or more on plates from other pots.

‡ All applications of dextrose were repeated 51 days after the experiment started. All pots excepting 1 and 2 received 10 c.c. of soil infusion.

± E for total dry weight = 1.1 gm.; Maximum E = 4 gm.; Minimum = .1.

± E for total count of Bact. = .75 M.; Maximum E 1.9 M.; Minimum = .047 M.

TABLE XIV. . YIELD OF OATS AND NUMBER OF BACTERIA DUE TO DIFFERENT TREATMENTS

Pot No.	Treatment ‡	Total dry weight gm. *	Difference due to treatment	Av. loss due to dext.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
3	10 c.c. of Soil Infusion	14.	00	00	.3	1.7	1.6	1.1	.6	.7	.6	1.8
4	"	14.	00	00	.3	1.0	1.3	.8	.9	.7	.5	.7
29	$\frac{1}{2}$ gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N)†	24.			.3	3.2	1.2	.6	.8	1.9	1.7	.9
30	"	25.	10.5		.3	4.0	2.6	.9	.7	1.2	1.5	1.1
31	$\frac{1}{2}$ gm. $(\text{NH}_4)_2\text{SO}_4$ + (R-N) + 30 gm. dextrose	17.			.3	15.0	13.2	10.0	21.1	15.3	9.1	6.4
32	"	19.	4	6.5	.3	13.0	12.7	8.7	22.7	15.7	13.0	5.7
33	1 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N)	36.			.3	2.9	1.1	.4	.7	1.3	1.0	.7
34	"	34.	21		.3	3.9	1.6	.7	.8	1.2	1.0	.5
35	1 gm. $(\text{NH}_4)_2\text{SO}_4$ + (R-N) + 30 gm. dextrose	20.			.3	22.7	20.7	12.7	23.9	19.3	11.1	7.1
36	"	21.	6.5	14.5	.3	23.9	23.3	11.6	23.3	17.7	17.7	6.3
37	2 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N)	44.			.3	4.1	4.0	.3	.6	1.8	1.1	1.0
38	"	42.	29		.3	3.2	5.2	.5	.4	1.4	1.9	1.2
39	2 gm. $(\text{NH}_4)_2\text{SO}_4$ + (R-N) + 30 gm. dextrose	24.			.3	23.4	22.4	8.8	27.7	23.4	11.9	5.7
40	"	23.	9.5	19.5	.3	25.6	22.2	7.3	28.7	20.0	10.6	6.9
41	3 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N)	45.			.3	3.1	1.1	.2	.4	1.2	1.0	.8
42	"	47.	3.2		.3	2.4	1.5	.9	.4	1.4	1.3	1.1
43	3 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N) + 30 gm. dextrose	23.			.3	27.2	18.7	8.0	28.9	13.0	7.7	7.9
44	"	25.	10	22	.3	29.9	17.1	7.6	29.3	10.0	5.1	6.8
45	4 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N)	53.			.3	3.3	2.0	.7	.9	1.0	.9	.4
46	"	55.	40		.3	2.7	2.7	.9	.6	.7	.6	.6
47	4 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N) + 30 gm. dextrose	26.			.3	9.9	14.4	5.6	30.4	16.7	6.4	8.1
48	"	26.	12	28	.3	32.4	16.2	8.7	33.5	15.3	6.7	6.1
49	5.6 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N)	51.			.3	2.6	1.5	.7	.7	1.6	1.6	1.3
50	"	49.	36		.3	3.8	1.9	.3	.9	1.1	1.7	1.5
51	5.6 gm. $(\text{NH}_4)_2\text{SO}_4$ (R-N) + 30 gm. dextrose	38.			.3	31.2	19.1	11.2	36.5	13.3	4.9	4.6

§ The application of dextrose was repeated 51 days after experiment started.

All pots received 10 c.c. of soil infusion.

* In recording total dry weight, quantiles less than 1 gram were recorded to the nearest gram, thus: 14.1 gm. scores 14 gm. and 13.9 gm. becomes 14 gm.

† (R-N) = Ration minus nitrogen.

‡ E. for total dry weight = 1.73 gm. Maximum E = 3 gm. Minimum = 1 gm.

‡ E. for total count of Bact. = .96 M. Maximum = 2.1 M. Minimum = .35 M.

(Continued on next page)

TABLE XIV. (Continued)

Pot No.	Treatment ‡	Total dry weight gm.	Difference due to treatment	Av. loss due to dext.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
52	"	36.	23	13	.3	29.7	20.2	9.1	34.7	11.7	5.1	6.0
53	8 gm. $(\text{NH}_4)_2\text{SO}_4 + (\text{R-N})$	48.			.3	4.1	1.0	.6	.7	1.1	1.0	1.1
54	"	45.	32.5		.3	3.8	.8	.7	8.0	1.2	1.3	1.3
55	8 gm. $(\text{NH}_4)_2\text{SO}_4 + (\text{R-N}) + 30$ gm. dextrose	35.			.3	29.0	16.4	6.8	34.4	10.7	5.9	6.3
56	"	38	22.5	10.0	.3	30.1	15.7	7.0	37.7	9.4	5.2	6.5

‡ The application of dextrose was repeated 51 days after experiment started.

All pots received 10 c.c. of soil infusion.

* In recording total dry weight, quantities less than 1 gram were recorded to the nearest gram, thus: 14.1 gm. scores 14 gm. and 13.9 gm. becomes 14 gm.

‡ (R-N) = Ration minus nitrogen.

± E for total dry weight = 1.73 gm.; Maximum E = 3 gm.; Minimum = 1 gm.

± E for total count of Bact. = .96 M.; Maximum = 2.1 M.; Minimum = .35 M.

TABLE XV. YIELD OF OATS AND NUMBER OF BACTERIA DUE TO DIFFERENT TREATMENTS

Pot No.	Treatment ‡	Total dry weight gm.	Difference due to treatment	Av. loss due to dext.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
1	10 c.c. of soil infusion	14.	00		.4	1.9	1.6	.8	.6	1.2	1.0	1.0
2	"	14.	00		.4	1.8	2.1	.8	.6	1.9	1.3	.7
3	2 gm. KNO ₃ + (R-N)	48.			.4	1.8	1.9	1.0	1.7	1.1	1.5	.4
4	"	51.	35.3		.4	2.0	1.1	1.8	1.1	1.6	1.3	.9
5	2 gm. KNO ₃ + (R-N) + 30 gm. dextrose	23.			.4	12.2	10.0	8.1	17.5	16.9	10.7	6.3
6	"	25.	10.0	25.5	.4	10.9	9.0	6.	21.4	14.2	14.5	9.0
7	3 gm. KNO ₃ + (R-N)	50.			.4	1.9	1.0	1.0	.9	1.3	.9	.5
8	"	53.	37.5		.4	2.3	2.7	.9	.8	1.0	.7	.6
9	3 gm. KNO ₃ + (R-N) + 30 gm. dextrose	24.			.4	10.7	10.1	7.4	23.7	21.5	19.1	11.
10	"	24.	10.0	27.5	.4	16.0	11.0	9.2	25.1	20.6	15.0	5.0
11	4 gm. KNO ₃ + (R-N)	52.			.4	.9	1.1	1.4	1.0	1.2	.5	1.1
12	"	51.	37.5		.4	1.1	1.1	1.2	.7	1.0	.6	.6
13	4 gm. KNO ₃ + (R-N) + 30 gm. dextrose	32.			.4	9.2	7.2	7.1	28.2	23.7	11.2	8.8
14	"	28.	16	21.5	.4	11.4	11.7	6.0	27.0	25.1	9.1	8.2
15	5 gm. KNO ₃ + (R-N) +	48			.4	.9	1.1	.7	1.2	1.8	1.7	1.0
16	"	49.	34		.4	1.1	1.4	1.0	2.1	2.2	1.5	.8
17	5 gm. KNO ₃ + (R-N) + 30 gm. dextrose	28.			.4	11.1	10.7	9.7	29.2	21.5	11.0	5.7
18	"	30.	15.	19.5	.4	11.6	12.4	5.1	27.7	27.0	13.3	8.4
19	6 gm. KNO ₃ + (R-N)	48.			.4	1.0	.7	.4	.9	1.1	.6	.4
20	"	47	33.5		.4	.7	.7	.6	1.7	1.5	.8	.5
21	6 gm. KNO ₃ + (R-N) + 30 gm. dextrose	41.			.4	10.1	9.2	4.4	28.7	11.0	4.7	3.5
22	"	16.*	27	6.5	.4	4.7	5.1	2.2	1.9	1.9	2.0	1.0
23	7 gm. KNO ₃ + (R-N)	33.			.4	.5	.4	.7	1.1	.9	.6	.4
24	"	31.	27		.4	.7	.8	.7	.6	.4	.5	.7
25	7 gm. KNO ₃ + (R-N) + 30 gm. dextrose	35.			.4	13.3	9.2	6.0	33.7	30.4	11.4	6.1
26	"	37.	22.0	5.0	.4	11.2	8.1	7.1	29.8	30.4	9.0	7.2
27	8.7 gm. KNO ₃ + (R-N)	30.			.4	1.0	.4	.2	.6	.6	.6	.5
28	"	30.			.4	1.0	.4	.2	.6	.6	.6	.5
29	8.7 gm. KNO ₃ + (R-N) + 30 gm. dextrose	38.			.4	9.4	7.4	6.5	34.3	11.4	8.7	7.0
30	"	38.	2.4	8	.4	8.3	7.9	7.1	36.7	10.2	6.9	5.8

‡ All pots received 10 c.c. of soil infusion.

* Results not included in E. All applications of dextrose were repeated 50 days after experiment started.

± E for total dry weight = 1.64 gm. Maximum E = 4 gm. Minimum E = 1 gm.

± E for total count Bact. = .55 M. Maximum = .91 M.; Minimum = .097 M.

work of Jensen (49) and by Oudemans and Koning, Adametz, Hagem and Dale, as reported by Goddard (50). While Goddard's own work on nitrogen fixation by fungi and the work of others summarized by him on the same subject seems to negate the value of these organisms as fixers of free nitrogen, it does not follow that they do not materially affect decomposition process in the soil. From the results of McBeth & Scales (51) and the literature cited by them and the more recent work of Scales (52) on the action of soil fungi, it is probable that they are often the first agents of destruction* of such soil organic matter which contains a high percent of cellulose**, particularly lignified and woody plants (53). The method of isolating and studying these organisms as used by the above investigators suggests that in the presence of cellulose these organisms may utilize available plant food. The writer wishes to reiterate the statement previously made regarding the futility of attempting to correlate soil fertility with the physiological activities of bacteria only.

Some quantitative work done by students at the North Dakota Agricultural College, under the supervision of the writer, showed that an agar medium containing the same nutrient salts as in media 1 with tartaric acid as a source of energy, and plated by the above dilution method gave as an average of 11 fields of Fargo clay the following counts of *Aspergillius* and *Pencillium* per gram of soil:

<i>Aspergillius</i>	340.000
<i>Pencillium</i>	710.000

These are by no means the only fungi in the soils as is indicated by qualitative work. Neither do they, in my opinion, represent a maximum of conidia for these genera.

Owing to the foregoing facts, the writer does not attempt to hold the bacteria responsible for the entire results that transpired in the sand of the following tests.

*Bibliography (51) pages 41 to 43.

**Consult the literature cited by McBeth and Scales. (51)

TABLE XVI. YIELD OF OATS AND NUMBER OF BACTERIA DUE TO DIFFERENT TREATMENTS

Pot No.	Treatment ‡	Total dry weight gm.	Difference due to treatment	Av. loss due to dext.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
1	10 c.c. soil infusion	14.	00	00	.4	1.9	1.6	.8	.6	1.2	1.0	1.0
2	"	14.	00	00	.4	1.9	1.6	.8	.6	1.2	1.0	1.0
31	1/2 gm. Ca(H ₂ PO ₄) ₂ + (R-P)*	36.		00	.4	1.8	1.0	1.1	.9	.3	1.1	.4
32	"	39.	23.5	00	.4	1.7	1.2	1.3	.8	.7	1.5	.9
33	1/2 gm. Ca(H ₂ PO ₄) ₂ + (R-P) + 30 gm. dextrose	20.			.4	10.4	9.1	4.4	21.4	11.4	7.3	6.5
34	"	21.	6.5	17.0	.4	12.2	7.8	5.3	27.3	9.9	7.9	5.8
35	1 gm. Ca(H ₂ PO ₄) ₂ + (R-P)	50.			.4	2.1	2.0	1.5	1.0	1.3	1.7	1.6
36	"	49.	34.5		.4	3.1	1.8	1.3	1.2	1.0	1.5	1.7
37	1 gm. Ca(H ₂ PO ₄) ₂ + (R-P) + 30 gm. dextrose	25.			.4	12.5	11.1	5.6	29.9	21.0	11.0	9.2
38	"	24.	10.5	24.0	.4	13.0	10.9	6.7	31.2	22.0	7.5	8.1
39	2 gm. Ca(H ₂ PO ₄) ₂ + (R-P)	51.			.4	1.3	1.2	1.0	1.0	.7	.7	.5
40	"	48.	35.5		.4	1.3	1.7	.4	1.9	.9	.6	.4
41	2 gm. Ca(H ₂ PO ₄) ₂ + (R-P) + 30 gm. dextrose	33.			.4	11.0	7.8	4.9	33.7	17.9	7.6	6.9
42	"	39.	22.0	13.5	.4	13.3	9.9	5.4	34.4	22.4	11.2	8.8
43	3 gm. Ca(H ₂ PO ₄) ₂ + (R-P)	50.			.4	3.1	1.4	.6	1.3	1.7	1.0	.7
44	"	49.	35.5		.4	3.8	1.8	1.0	1.0	1.8	1.0	.3
45	3 gm. Ca(H ₂ PO ₄) ₂ + (R-P) + 30 gm. dextrose	38.			.4	9.6	7.7	4.3	38.7	22.2	9.6	7.4
46	"	36.	23.0	12.5	.4	10.7	7.6	5.7	35.3	23.8	13.5	11.5
47	4 gm. Ca(H ₂ PO ₄) ₂ + (R-P)	56.			.4	4.3	2.5	2.5	1.6	1.4	1.0	0.7
48	"	52.	40.0		.4	1.9	1.1	.8	1.1	1.6	1.7	1.3
49	4 gm. Ca(H ₂ PO ₄) ₂ + (R-P) + 30 gm. dextrose	38.			.4	10.5	5.0	5.1	30.1	19.7	7.5	6.6
50	"	36.	23.0	17.0	.4	10.7	9.8	4.8	28.5	23.2	11.3	8.1
51	5 gm. Ca(H ₂ PO ₄) ₂ + (R-P)	54.0			.4	2.9	1.7	1.1	1.3	1.7	1.4	1.3
52	"	51.	38.5		.4	1.8	1.0	.6	.7	.8	.5	.3
53	5 gm. Ca(H ₂ PO ₄) ₂ + (R-P) + 30 gm. dextrose	39.			.4	10.1	6.3	5.5	27.9	15.5	9.2	8.6

* (R-P) = Ration minus phosphorus.

‡ All applications of dextrose repeated 50 days after experiment started.

All pots received 10 c.c. of soil infusion at the beginning.

± E for total dry weight = 2.8 gm. Maximum E = 6 gm. Minimum E = 1 gm.

.05 M. E for total count Bacteria = .33 M. Maximum E = 1.15 M. Minimum E =

(Continued on next page)

TABLE XVI. (Continued)

Pot No.	Treatment §	Total dry weight gm.	Difference due to treatment	Av. loss due to dext.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
54	"	42.	26.5	12.0	.4	9.2	6.0	4.8	33.5	21.4	11.7	7.2
55	6 gm. $\text{Ca}(\text{H}_2\text{PO}_4)_2 + (\text{R-P})$	52.			.4	2.3	2.2	2.0	2.3	.7	.9	.6
56	"	55.	39.5		.4	3.4	2.3	1.5	1.8	1.5	1.4	1.1
57	6 gm. $\text{Ca}(\text{H}_2\text{PO}_4)_2 + (\text{R-P}) + 30$ gm. dextrose	33.			.4	13.3	7.7	3.9	31.9	12.2	9.5	7.3
58	"	39.	22.0	17.5	.4	14.1	8.7	6.8	35.0	19.6	10.9	6.4

* (R-P) = Ration minus phosphorus.

§ All applications of dextrose repeated 50 days after experiment started.

All pots received 10 c.c. of soil infusion at the beginning.

± E for total dry weight = 2.6 gm. Maximum E = 6 gm. Minimum E = 1 gm.

± E for total count Bacteria = .33 M. Maximum E. = 1.15 M. Minimum E = .05 M.

TABLE XVII. YIELD OF OATS AND NUMBER OF BACTERIA DUE TO DIFFERENT TREATMENTS

Pot No.	Treatment ‡	Total dry weight gm.	Av. Difference due to treatment	Av. loss due to energy material.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
1	10 c.c. soil infusion	14.			.4	1.9	1.6	.8	.6	1.2	1.0	1.0
2	"	14.			.4	1.8	2.1	.8	.6	1.9	1.3	.7
59	120 gm. W. R. M. 5 c.c. 72 hr. culture B. mycoides 30 gm. dextrose	32.			.4	19.0	6.0	4.0	2.2	20.0	15.0	15.1
60	"	33.	18.5	2.0	.4	13.0	8.0	6.1	2.7	19.0	14.0	11.9
61	120 gm. W. R. M. 5 c.c. 72 hr. cult. mycoides	37.				19.0	6.3	6.3	6.0	5.5	5.2	4.9
62	"	35.	20.5		.4	11.0	7.9	8.1	7.0	6.5	6.0	5.5
63	120 gm. W. R. M. + (R-N)	35.			.4	17.3	15.9	12.3	11.1	11.2	8.7	8.7
64	"	35.	21.0		.4	21.0	18.4	13.3	12.0	10.9	9.6	7.4
65	120 gm. W. R. M. + (R-N) + 150 gm. straw	33.			.4	5.1	5.3	5.8	4.7	5.9	7.2	6.6
66	"	32.	18.5	2.5	.4	7.5	6.9	6.3	6.9	6.0	5.7	5.8
67	120 gm. W. R. M. + 150 gm. straw	31.			.4	5.3	4.7	4.8	4.3	3.8	4.2	3.3
68	"	31.	17.0	†4	.4	4.4	4.9	5.0	4.6	4.1	3.9	3.7
69	120 gm. W. R. M.	27.			.4	9.9	8.6	6.4	6.5	6.0	4.2	4.1
70	"	27.	13.0		.4	10.7	9.3	7.1	6.7	5.8	5.7	5.3
71	204 gm. F. H. M.	27.			.4	13.7	11.2	7.6	6.0	6.1	5.2	4.2
72	"	22.	10.5		.4	15.8	15.3	9.9	7.3	5.3	4.4	2.7
73	204 gm. F. H. M. + 150 gm. straw	27.			.4	10.2	5.4	6.7	6.0	4.3	4.4	4.3
74	"	26.	12.5	†2	.4	8.1	7.3	7.0	6.3	6.1	5.4	5.2
75	204 gm. F. H. M. + (R-N)	24.			.4	16.7	14.4	6.3	6.4	5.8	5.5	5.2
76	"	27.	11.5		.4	15.4	15.1	11.0	7.7	4.1	4.1	3.9
77	204 gm. F. H. M. + (R-N) + 150 gm. straw	25.			.4	11.9	11.0	7.6	5.3	5.5	5.4	5.1
78	"	23.	10.5	1.0	.4	8.3	13.2	9.2	7.8	4.9	4.9	4.7
79	204 gm. F. H. M. 8.7 gm. KNO ₃ + 150 gm. straw	14.			.4	17.4	15.5	15.7	15.3	11.2	7.6	7.7
80	"	12.	loss of 1 gm.	17*	.4	19.1	14.9	15.1	14.4	9.9	8.5	6.4
81	8.7 gm. KNO ₃ + 150 gm. straw	30.			.4	6.2	5.5	4.6	7.2	7.3	6.8	6.5
82	"	30.	16.0	0	.4	5.9	5.9	5.1	6.1	7.8	6.3	5.3
83	150 gm. straw	24.			.4	1.0	1.3	1.2	2.2	4.2	3.7	4.1

§ All pots received 10 c.c. of soil infusion.

* Compare with nitrate controls Pots No. 19 and 20. Table XIV.

° Probably an error in analysis.

‡ Compare with ammonia controls. Pots No. 17 and 18.

W. R. M. = Well rotted manure.

F. H. M. = Fresh Horse Manure.

± E for total dry weight = 1.44 gm. Maximum E = 5 gm. Minimum E = 1 gm.

+ E for total counts Bact. = .47 M.; Maximum E = .77 M.; Minimum E = .017 M.

† Gain.

(Continued on next page)

TABLE XVII. (Continued)

Pot No.	Treatment ‡	Total dry weight gm.	Av. Difference due to treatment	Av. loss due to energy material.	Millions of bacteria per gm.							
					At beginning	17 days	31 days	45 days	59 days	73 days	87 days	100 days
84	"	26.	11.0	†11	.4	.7	1.1	1.7	3.4	3.9	4.4	5.0
85	5.6 gm. (NH ₄) ₂ SO ₄ + 150 gm. straw	26.			.4	4.4	5.0	4.7	6.3	8.2	7.7	6.6
86	"	25.	11.5	†38.5	.4	5.3	5.8	5.8	6.1	9.2	5.8	7.2
87	8.34 gm. casein + (R-N)	43.			.4	17.6	14.3	9.4	4.4	3.6	3.7	2.8
88	"	47.	31		.4	16.8	12.1	7.2	5.1	3.0	2.9	3.1
89	8.34 gm. casein + (R-N) + 30 gm. dext.	26.			.4	55.4	22.9	13.7	46.9	19.0	9.2	4.4
90	"	27.	12.5	18.5	.4	41.3	31.0	11.4	61.4	28.0	8.3	3.1
91	8.34 gm. + (R-N) + 150 gm. straw	30.			.4	16.	15.0	14.1	9.6	5.5	3.3	3.2
92	"	29.	15.5	15.5	.4	13.1	13.9	10.2	9.1	7.2	4.1	2.9

‡ All pots received 10 c.c. of soil infusion.

* Compare with nitrate controls Pots No. 19 and 20. Table XIII.

° Probably an error in analysis.

† Compare with ammonia controls. Pots No. 17 and 18. Table XIII.

W. R. M. = Well rotted manure.

F. H. M. = Fresh Horse Manure.

± E for total dry weight = 1.44 gm. Maximum E = 5 gm. Minimum E = 1 gm.

± E for total counts Bact. = .47 M.; Maximum E = .77 M.; Minimum E = .017 M.

† Gain.

THE POT TESTS—THEORIES AND DISCUSSIONS.

In order to make the results in tables XIII to XVII conclusive, quantitative analysis should have been made on the ammonia and nitrate nitrogen, phosphorus and dextrose of the respective series. This, however, would have imposed more work than was possible along with the bacterial estimations.

In discussing the foregoing, it will be attempted to present each series so as to compare the effect of treatment upon the yield of oats and on the bacterial counts.

Tables XIII contains the controls. It was the purpose of these controls to determine the effect of the sand, its flora and chemical content upon both crop and bacterial development. In pots No. 1 and 2, may be noted the effect of the untreated sand upon yield and development of bacteria under green-house conditions. The yielding power of the untreated sand was 14 grams of dry matter per pot. Accompanying this we note a bacterial development that at no analysis exceeded more than 1.6 millions of bacteria per gram. The oats in pots one and two were apparently free from disease throughout the experiment. A spindling growth and light green color, however, was ample evidence of insufficient nutrition. Yet there was still sufficient material in the soil to support an increased bacterial growth of from two to five times the number present at the beginning. These results may be regarded as due to the inherent physical, chemical and biological properties of the quartz sand under green-house conditions. It may be assumed that variations from these results were due to treatment. The results of pots 3 and 4 differ

from pots 1 and 2 by a slight increase in weight of dry matter and an increase in the number of bacteria. The increase in dry weight is less than the value of the experimental error. Therefore, within the limits of the methods used, the only effect of the addition of an infusion of soil bacteria was to cause an increase in the number of bacteria. Theoretically, the increase in the number of bacteria might lead to one of the following results. First: an increase in the number of bacteria might result in an increase in the amount of available plant food, in which case it should be registered as a distinct increase in yield of oats. Second: the increase in the number of bacteria might result in an increased consumption of available plant food by the bacteria which, if long continued, should be registered as a decrease in yield of oats, providing there was not sufficient material for the nutrition of both bacteria and oats. Third: the increase in the number of bacteria and consumption of plant food by them would continue as long as excess energy was available, after which there would be an increased liberation of plant food due to the increased number of bacteria acting on nitrogenous matter with a lower ratio of energy to nutrients. If the excess energy were exhausted late in the experiment, a decrease in the yield of oats similar to the second theoretical consideration might be expected. If the excess energy were exhausted early in the experiment, there might be expected an increase in yield similar to the first theoretical consideration. However, we are dealing with such a small quantity* of nitrogen (approximately .6875 gm. total nitrogen), that either theoretical consideration the first or the third would answer. The apparent rate of growth throughout the experiment was so meager that observation failed to note retarding or accelerating influences; therefore, for the purposes of this experiment the application of 10 c.c. of a (1 to 5) soil infusion may be regarded as without influence upon the yield of oats. In making comparisons of yield with other treatments either pots one and two, or three and four, may serve as a basis, but pots 3 and 4 must be the basis of comparison for bacterial changes. For this reason pots 3 and 4 will be used for comparisons of both yield and bacterial changes.

Pots 5 and 6 received 1 gram of dextrose at the beginning of the experiment and 51 days later a second application of 1 gram. Apparently there was a slight increase in yield. This increase was less than the value of experimental error for the series. If it had not been for the second application of dextrose, there might have been a distinct increase in yield and support of the results obtained on stimulation of ammonification with .05% dextrose in the presence of casein as shown in Table VII. However, here, too, a limited

*The 14 grams oats analyzed 1.11% nitrogen. The total nitrogen present was approximately .6875 grams. Therefore
$$\frac{.6875 - (1.11\% \text{ of } 14)}{18120 \text{ g}} = .0000293$$
 gm. N per 100 grams of soil or .00293%.

It is interesting to note in this connection that the percent of nitrogen in the crop of oats increased as the quantity of nitrogen in the pots increased. For example, Pots 1 and 2, 3 and 4 contained 1.11% while in those pots containing 8.7 grams of KNO_3 the % of nitrogen in the pots was 2.81%. This agrees with the results obtained by Lipman and associates.—Bull. 257, New Jersey Experiment Station.

quantity of plant food was present so that the nitrogen, at least, was withdrawn to a low limit of dilution.

The influence of the one gram applications of dextrose was distinctly visible on the bacterial numbers; there was a marked rise in numbers after each application, followed by rather sharp declines. The rise in numbers was evidently due to dextrose furnishing energy. This increase in the number of bacteria to 7 or 8 millions must result either in the assimilation of considerably more plant food or in the destruction of more nitrogenous matter than took place in pots 3 and 4. In either case the amount of organic material transformed into bacterial organic matter was greatly increased. Even at the end of the experiment there was from three to four times as much living bacterial organic matter as in pots 3 and 4. There were probably considerable numbers of dead and inert bacterial cells in the sand, of which the count gives no record. According to the theory previously advanced there should have been either a marked increase or decrease in oat yield compared with pots 3 and 4, but it is possible that the presence of dextrose enabled the microorganisms to split off nitrogen from the more inert nitrogenous compounds within the sand and thus secure the necessary nitrogen without materially affecting the limited amount left over for the plants. The question naturally arises did nitrogen fixation take place in the presence of the dextrose? Total analysis* of the nitrogen removed by the oats and that which remained within the sand shows there was no increase in nitrogen. With pots 7 and 8 where 5 grams of dextrose was added there was apparently no effect upon yield or rather such influence as was exerted was not registered in yield of oats, but there was a distinct influence upon the numbers of bacteria (27). The 5 grams of dextrose acted in apparently the same way as 1 gram. On the other hand, with 30 grams of dextrose there was a sharp decrease in yield (25), approximately 34%. From the data of pots 9 and 10 we may draw the following conclusions: Either there was no assimilation of available plant food with the 1 and 5 gram applications of dextrose, or the period of assimilation was so short that the greater number of bacteria thus induced was able to replace the plant food absorbed after the excess energy had disappeared. (See Table VII). When 30 grams of dextrose was used, there was not sufficient time after its disappearance for the nutrients in excess of bacterial requirements to accumulate for plant use. This line of reasoning is further exemplified from the competitive point of view by the bacterial counts. From 45 to 50 days after the application of 1 or 5 grams of dextrose the number of bacteria had dropped to 3.5 millions or less, whereas with 30 grams of dextrose 5.3 was the lowest. This indicates that more of the plant food was locked up in living bacterial bodies. This line of reasoning is not infallible because of the unknown number of dead or inert bacterial cells or of the cells of other microorganisms that may be present where the fewer active bacteria are found.

There is one other point in connection with the results from 30 grams of dextrose. The 30 grams of dextrose caused apparently no greater number of bacteria than the one gram. The 5 grams has

*The data was not included in the tables on account of lack of space.

a slight advantage over either. This might be explained by the assumption that the 30 grams was creating an unfavorable osmotic condition, while the optimum condition lay somewhere between 5 and 30 grams. In view of the fact that only a limited amount of nitrogen was present in the soil, it is probably that nitrogen or some other food element was the limiting factor to bacterial multiplications. For confirmation of this view note the number of bacteria where 30 grams of dextrose is used with abundant ammonia, manure or casein nitrogen and other food constituents.

In pots 11 to 16 a fairly uniform yield of oats occurred regardless of whether nitrogen or phosphorus was lacking; yet in pots 15 and 16 where all nutrients except $\text{Ca}(\text{H}_2\text{PO}_4)_2$ was used, there was a lower bacterial count. Evidently, there was less phosphorus in the untreated sand than other food elements. In pots 11 and 12 and 13 and 14, the increase of bacteria is notably greater where all elements except nitrogen were added than in 15 and 16 where all elements excepting phosphorus were added, but there was no such increase in the number of bacteria as occurred upon the addition of dextrose. This indicates that it was energy material which caused the marked rise in numbers of bacteria in pots 5 to 10. This view is amply sustained by the total counts on pots 17 to 22 where full nutrients were added. In these pots there was sufficient food elements to sustain an immense number of bacteria, but the number did not exceed those in the pots which were short on one necessary element. Possibly, though, the bacteria do not readily use these chemicals which are so available to higher plants. This view is not sustained by the results of pots 31 and 32. When energy material was present the bacteria increased in numbers with increase in plant food. Likewise the yield of oats in pots 17 to 22 was the greatest secured from any pots and served to show that the chemicals employed were abundant and readily available to oats.

Pots No. 23 and 24 received 30 grams dextrose and all necessary plant foods except nitrogen. The shortage of nitrogen in these pots was assumed to be ammonia nitrogen. The results in yield of oats and increase in number of bacteria are quite similar to pots 9 and 10. Evidently, it was dextrose which caused the difference in yield between pots 11 and 12 and 23 and 24 because they were otherwise treated alike. Likewise it was dextrose which caused the increase of bacteria in pots 23 and 24 over those in pots 11 and 12. Furthermore it was the shortage of nitrogen in pots 23 and 24 which held the bacterial numbers practically the same as those in pots 5 to 10. This also explains the result in pots 25 and 26, and 27 and 28. In pots 5 and 10 there is a nitrogen shortage and in the latter a phosphorus shortage.

In Table XIV the pots received 10 c.c. of soil infusion. All excepting 3 and 4 received all nutrients, excepting nitrogen which was added at the rate of one half gram of ammonium sulphate to pots 29 and 30, one gram, to 31 to 34 and increased one gram for each subsequent set of 4 pots up to pot 48. Pots 49 to 52 received 5.3 grams of ammonium sulphate, the nitrogen equivalent of 8.7 grams KNO_3 , while pots 53 to 56 received 8 grams of ammonium sulphate. From pot 29 on to 56 every other set of two received 30 grams of

dextrose. This gives a means of checking some of the suggestions and theories advanced for explanation of the results in Table XIII. In Table XIV it is evident that a full supply of nutrients materially affected the yield of oats, but did not greatly increase the number of bacteria. As far as the number of bacteria was concerned, there was apparently no difference in effect of $\frac{1}{2}$ gram ammonium sulphate and a full supply of all other nutrients, while with the oats there was a marked increase up to 4 grams of ammonium sulphate. With a supply of from 4 grams to 8 grams of ammonium sulphate there was a slight decrease in the yield of oats, thus confirming the work of Maze (54), who pointed out that ammonium sulphate in too great concentration is toxic to maize. On the other hand, where ever dextrose was added there was a depression in the oat yield and an increase in bacterial numbers until the amount of ammonium sulphate exceeded 4 grams, after which the number of bacteria was practically constant. Evidently a concentration of 4 grams of ammonium sulphate in the presence of 30 grams of dextrose, in conjunction with the other chemical, physical and biological factors allowed the maximum developments of bacteria. Consequently, as far as the competitive action of the bacteria is concerned, it may be regarded as having reached its maximum. All further increase in addition of ammonia should be at the disposal of the oats and we could expect in the presence of dextrose that additions of ammonia above 4 grams would result in an increased yield. The yields of pots 51, 52, 55 and 56 confirms this view; but it is evident that some other depressing influence was present. Pots 45 and 46, which received 4 grams of ammonium sulphate, but no dextrose, gave the maximum yield of oats; therefore, within the limits of this experiment, 4 grams of ammonium sulphate gave ample nitrogen for the maximum oat yield. Furthermore, pots 47 and 48 which received 4 grams of ammonium sulphate and 30 grams of dextrose gave sufficient nitrogen for a maximum bacterial increase; therefore, pots 55 and 56, which contained sufficient nitrogen for a maximum bacterial development as well as sufficient nitrogen for a maximum oat yield should have produced as much dry weight of oats as pots 45 and 46 and should have had as many bacteria present as found in pots 47 and 48. The number of bacteria is approximately correct, but the yield of the oats is 10 grams below that which it should have been if competition was the only retarding factor. Therefore, it may be concluded that the 30 grams of dextrose exerted a retarding influence upon the oat development, either directly due to toxic or osmotic action or indirectly, due to the action of decomposition products from the dextrose, or both. At the same time it is evident that quantities of ammonium sulphate above 4 grams per pot also exerted a retarding influence upon the oats. The retarding influence of the dextrose may be measured by the difference between the weight of oats from pots 43 and 44 and those of pots 55 and 56, which amounts to 10 grams, while the depressing effect of 8 grams of ammonium sulphate may be measured by the difference in yield between pots 45 and 46 and pots 53 and 54. This difference amounts to 7.5 grams. Therefore, under optimum concentration of nitrogen as ammonium sulphate, the

competition of bacteria* in the presence of 30 grams of dextrose depressed the yield of oats approximately $54^{**} - (25^{***} + 10^{****}) = 19$ grams which is approximately 35.18%.

In order to test this theory in regard to nitrate nitrogen, nitrogen in casein, well rotted manure, fresh horse manure, with dextrose and straw as sources of energy and phosphorus in the presence of dextrose, another large series of pots were run along lines similar to the preceding. Sand from the same source and of the same physical composition was secured and analyzed bacteriologically and for total nitrogen with the following results. Bacterial count 450,000; total nitrogen, 3.6 mgm. per 100 grams sand.

Owing to the fact that no difference was observed in Table XIII between the untreated sand and that receiving 10 c.c. of bacterial suspension, the untreated pots were omitted. All pots in the series received 10 c.c. of soil infusion. Likewise, because $\frac{1}{2}$ and 1 gram applications of ammonium sulphate were not significant regarding oat yield, their equivalents were omitted in the nitrate test while 1 gram was the smallest quantity of phosphorus added. Equivalent quantities of nitrogen were added in all cases except where straw or fresh horse manure was used as a source of energy, in which cases no allowance was made for the nitrogen contained in the straw and manure. The exact treatment and results are given in Tables XV, XVI and XVII.

The yield of oats recorded in Tables XV and XVII confirm the results obtained with ammonia nitrogen. Dextrose tends to reduce the yield of oats when applied with nitrogen as nitrate, ammonia, or in casein, well rotted manure, or fresh horse manure. The same is true of phosphorus added as $\text{Ca}(\text{H}_2\text{PO}_4)_2$. The addition of straw did not always give consistent action, probably because of the nitrogen which it contained. Varying results can not be attributed to parasitic organisms because the straw was sterilized in the autoclav at 25 lbs. for 30 minutes. This is quite clearly brought out by a comparison of the results of pots 63 and 64 with 65 and 66, also 67 and 68 with 69 and 70. The addition of 150 grams of straw alone in pots 83 and 84 increased the yield over the check about 11 grams. However, when the effect of straw on ammonia-sulphate; pots 85 and 86, Table XVII is compared with the same amount of ammonia sulphate, pots 49 and 50, Table XIV, there may be seen a marked depressing (25) effect upon oat yield. The results are not quite so clear with straw and nitrates. Compare pots 81 and 82, Table XVII with pots 27 and 28, Table XV. This concentration of nutrients is inhibitive. On the other hand, the protective action of dextrose in the presence of excess nitrate is more pronounced than the protective action with ammonium sulphate, pots 23 to 30, Table XV, shows that the consumption of nitrates, where excess nitrates was added in the presence of dextrose actually was able to increase the yield of oats by removing some of the nitrates in excess.

*Also other organisms.

**Yield of oats, optimum nitrogen concentrated pots 45 and 46.

***Yield of oats, optimum nitrogen 30 grams dextrose, pots 47 and 48.

****Depression of oat yield due to dextrose pots 55 and 56.

In order to draw particular attention to casein in the presence and absence of dextrose upon oat yields so as to connect pure culture work presented in the beginning, we will consider here the results with casein. It is evident that casein with other plant nutrients is almost as efficient a source of nitrogen as ammonium sulphate and potassium nitrate, but when used with dextrose, the decrease in yield was marked, but not quite as marked with straw. The addition of 5 c.c. of a 72 hour culture of *B. mycoides* to well rotted manure, pots 59 to 62, in the presence of and absence of dextrose did not give results as striking as could be desired. The addition of 204 grams of fresh horse manure and 150 grams of straw to 8.7 gram of KNO_3 was strikingly effective. Analysis* for total nitrogen shows that only 1.1% of the nitrates was lost by denitrification, assuming that such loss comes from nitrate nitrogen only. Therefore, the cause of the marked decrease in yield must be sought elsewhere (28). The following explanation appears feasible: The fresh horse manure introduced great numbers of nitrate consuming organisms which consumed the nitrates. If this was true, those organisms did not appear in great numbers upon the plates.

There are three significant points to be noted with the bacterial counts in Tables XV to XVII. First, the presence of nitrate** nitrogen does not greatly increase the number of bacteria even in the presence of dextrose. Compare the counts of pots 8 and 10 and 23 and 28, Table XIII with those of Tables XV and XVI where nitrates and dextrose were used. It is obvious that the disappearance of the nitrates which caused a reduction in the yield of oats was not due to bacteria alone, but most probably to molds which emphasizes the statement: that "the influence of microorganisms upon a soil's fertility cannot be measured by bacterial study alone". Furthermore, the work of the soil bacteriologist can never attain its full effect in the solution of soil problems until we learn more fully the activities of the soil molds, and also yeast, algae, and protozoa. In a word, the study of soil bacteriology must be broadened into soil microbiology. The second significant fact is that the bacterial count was higher in the nitrate series after the second application of dextrose than it was after the first. Third, the application of well rotted manure, fresh manure, and casein caused a large increase in the number of bacteria (27 and 28).

It, therefore, becomes apparent that under the conditions of the experiment where dextrose is present to furnish energy, bacteria are able to compete with oats for soluble plant food when the nitrogen is added as ammonia or in organic forms that may be converted into ammonia. On the other hand when the nitrogen is added as nitrates under the above conditions, molds are most probably the most vigorous competitors. Considering the ability of molds to assimilate† ammonia nitrogen, it may be assumed that they also rob the plants of ammonia in the presence of excess available energy.

*This is the only instance in the entire series where there was less nitrogen at the end than at the beginning of the experiment. If denitrification took place elsewhere, it was masked by nitrogen fixation.

**Nitrate nitrogen was used in Table XVI or the phosphorus series.

†Bibliography 1, 3, 4, 5, 13 and 15.

From the results obtained with $\text{Ca}(\text{H}_2\text{PO}_4)_2$, Table XVI it may be assumed that the other elements of available plant food are likewise utilized by microorganisms under suitable conditions. By the results obtained in such pots as contained more plant food than the maximum number of microorganisms could consume with the energy obtained from 30 grams of dextrose, enables the deduction that available plant food may be regarded as bacterial food which is in excess of available energy.

Having established the fact that beneficial bacteria as well as others not known to be beneficial, utilize available plant food in the presence of suitable energy supply, it follows that these same bacteria will utilize the available plant food liberated from organic matter under similar conditions. Within certain limits, the rate of liberation of available plant food will increase as the available energy decreases. Since the energy incorporated into the building cell is undoubtedly less than the amount liberated from the original energy material, it follows that after the excess energy material is exhausted and the microorganism dies for lack of sufficient nutrition or from other causes, its cell constituents will contain a lower energy nutrient ratio than the parent organic matter; consequently, decomposition of successive generations of organic matter will result eventually in the nutrient materials being in excess of the energy material and there may be expected an accelerated liberation of plant food with each succeeding generation of microorganisms. Here too, one finds at least one reason for the acceleration of ammonification after soils are dried or was partially sterilized. The transformation of available plant food into unavailable organic forms; in regard to ammonia and nitrate nitrogen, usually spoken of as transformation into proteins, is only temporary. The fact that under certain conditions it may result in a slightly depressed yield must not be regarded as a detrimental action any more than the consumption of oats by a draft horse; because these microorganisms must have nutrients as well as energy to carry on their work of liberation of plant food elements from organic matter. Assuredly the microbe is worthy of its hire. It does not follow that all microorganisms present in a soil are essential. It is highly probable that an exhaustive knowledge of the food requirements of each member of a flora would show that certain members might be eliminated with profit. Neither do the above results indicate that some of the energy forming materials must be eliminated from manures. If we would get the best possible results out of a flora, we must learn to feed it for maximum output. Such a system may mean more energy material than now given and that more time be given for the microorganisms to accomplish their work before the crop begins to press in its demands for food. Before it is attempted to regulate the energy nutrient ratio for soil microorganisms, the unsolved question of nitrogen fixation by *azotobacter* must be worked out that it may be known what proportion of energy material is necessary for most efficient nitrogen fixation as well as the amount necessary for the most suitable rate of plant food liberation. Under suitable physical and chemical conditions, the nearness to which the number of bacteria approach the possible maximum is

governed by the limiting bacterial food element. Among these food elements may be considered energy material. It is probable that energy material is quite frequently the limiting material in average soils, particularly after the period of rapid transformations has taken place following the addition of organic matter.

It is probable that in the presence of excess available energy, the amount of available plant food is* indirectly proportional to the number of microorganisms present. Since the amount of readily decomposable energy material** is usually small and the rate of decomposition comparatively rapid, the period of maximum consumption of available plant food by microorganisms is of short duration. Therefore, within certain limits, the greater the number of decay microorganisms present, the more rapid will be the decomposition of the energy material and the more rapid the narrowing of the energy nutrient ratio, and the consequent accelerated liberation and accumulation of available plant food. After the elimination of the excess energy the greater the number of decay microorganisms the greater the amount of available plant food liberated. However, it does not follow that the amount of available plant food is proportional to the number of microorganisms present. Here is where the real stumbling block to the conception of the relation of microorganisms (in terms of common parlance "decay* bacteria", "beneficial bacteria", "ammonifying bacteria") to available (nitrogen) plant food is found. It is generally assumed that any given (ammonifying) (beneficial) decay (bacterium) microorganism, acting upon (nitrogenous) organic matter, works at its individual maximum at the given soil temperature, moisture and chemical condition, and as a consequence, it has been further assumed that this individual bacterium multiplied by millions should deliver so many milligrams of (ammonia) available plant food per time unit.

Figuratively, it has been assumed that an engine working under certain conditions should deliver at the wheel so many foot pounds of energy for every ton of coal consumed, regardless of the fuel value of the coal supplied and regardless of the working efficiency of different engines. Consequently, it has been disappointing to find that one could not interpret soil fertility in terms of bacterial numbers. This conception has also led to the belief that the ammonifying power of a soil should be proportional to the number of ammonifying bacteria present.

Aside from such factors as physiological efficiency, non-ammonifying bacteria, ammonifying and non-ammonifying molds, soil protozoa, soil bacteria toxins, lack of an adequate medium for counting etc., it has not been possible to judge a soil's fertility by its bacterial numbers or ammonifying power because the energy nutrient ratio of complex bacterial flora is not known. Neither is the available energy nutrient ratio of the soil organic matter known at the time

*Plants seem able to gather certain amounts of plant food even under the most severe competitive conditions. In all probability, plants differ greatly in their ability to compete with microorganisms.

**Cellulose and starches are included.

*Used in its broadest sense to indicate all microorganisms which cause the decomposition of organic matter.

of comparing total counts with ammonifying power. Furthermore, even if the complex bacterial flora and its energy nutrient ratio was known and it was possible also to determine the available energy nutrient ratio of the soil organic matter at the time of analysis, there would still be discrepancies between total count and ammonifying power or even total count of ammonifying bacteria and the ammonifying power because at the inception of decay of the organic matter, the bacterial count rises and the rate of accumulation of ammonia from the decomposing soil organic matter falls. On the other hand after the exhaustion of excess available energy material, the bacterial numbers remain more or less constant (23) for a period while the rate of liberation of ammonia probably continues to increase for a time. Therefore, a count of the number of bacteria at the inception of decay and a determination of the ammonifying power of the soil by the present method will give a lower ammonifying coefficient per bacterial count than would be obtained from the same soil at a later period of decay, while neither would show a comparable relation to the rate of accumulation of plant food within the soil.

What effect would such action of microorganisms as previously described have upon nitrification? It is the prevailing belief that nitrification does not take place in the presence of organic matter, although this belief has been recently attacked by Stevens, Lipman and others. Such a belief is untenable because there is a vast amount of organic matter in any soil. For example, it has been recently pointed out by Swanson (63) that 150 tons of vegetation were necessary to produce the organic matter in some typical Kansas soils. Nitrification must take place, therefore, in the presence of organic matter, otherwise all our fertile soils would not cause nitrification. In this connection, see Coleman (10) and Karpinski and Niklewski (11) and Stevens and Withers (64). Patterson and Scott (24), say that starch and sugar retard nitrification. Enberding (27) found that starch and sugar would retard the activities of the nitrifying bacteria. Ehrenberg (26) states that straw will retard too rapid nitrification. What then is the explanation for the conflicting opinions on the influence of organic matter upon nitrification? The explanation is probably similar to that for the influence of organic matter upon ammonification.

The presence of organic matter upon soil nitrification acts in two ways to retard nitrate accumulation. First, the presence of excess energy material permits the assimilation of ammonia by ammonia consuming saprophytes, thereby leaving smaller quantities of ammonia to be nitrified. Second, the presence of excess energy material allows the assimilation of the nitrates by nitrate consuming saprophytes, thereby preventing the accumulation of nitrates.

These two processes occur simultaneously. The former actually lessens nitrification by removing the nitrifiable ammonia, the latter only apparently retards nitrification by preventing the accumulation of nitrates.

It would seem reasonable that if the preceding hypothesis concerning the ability of soil microorganisms to consume available plant food are correct, it should be possible to measure the amount of

consumption by chemical analysis. In order to test this view, experiments were arranged to include soil from the general farming section of the agricultural department and plots of ground selected and treated with heavy applications of finely chopped straw. The soils selected are classed as Fargo clay and are located upon land of the North Dakota Experiment Station. In all tests here recorded, duplicate 100 gram portions of fresh soil was treated by the beaker method used for ammonification and incubated at room temperature. Since nitrogen is so often the limiting element in crop production and the results of nitrogen consumption by soil organisms would have a direct bearing on the previous discussions of ammonifications, ammonia nitrogen was selected for the test. It was also found possible to include nitrate nitrogen in the study. These studies cover a period of more than two years and much data has been secured. A few of the determinations which are typical of different phases are here presented.

* METHODS IN DETAIL.

Five samples of soil were taken to a depth of 8⁺ inches from each plot. These were sieved and mixed thoroughly and a 100 gram sample taken for immediate moisture determination. Special care was taken to include all undecomposed organic matter. The portions for the tests were weighed out immediately after sieving and placed in sterile tumblers and covered with sterile petri dishes. To each 100 gram portion was then added approximately 100 mgm. of ammonium sulphate in solution or when nitrates were used, 50 mgm. of KNO_3 . The amount of ammonia nitrogen and nitrate nitrogen added to the soil was immediately determined by analyzing in duplicate 100 gram portions of the treated soil. The amount obtained was considered the amount of ammonia or nitrate nitrogen added. After the addition of the nitrogen, the water* content of the soil was brought up to the optimum** by the addition of distilled water. The following will illustrate the method of treatment for each soil.

DETERMINATIONS MADE THE SAME DAY THE SAMPLES WERE TAKEN

1	4—100† gm. portions	for residual ammonia determination.
2	4—100 " "	+100 mgm. $(\text{NH}_4)_2\text{SO}_4$ for ammonia added.
3	4—100 " "	for residual nitrate determinations.
4	4—100 " "	+20 mgm. KNO_3 for Nitrate added.
5	4— 5 " "	for total Nitrogen.

DETERMINATIONS MADE AT END OF 6 DAYS

6	4—110 gm. portions	for total N and residual NH_3 at end of experiment.
7	4—110 " "	+100 mgm. $(\text{NH}_4)_2\text{SO}_4$ for total N and ammonia consumed.
8	4—110 " "	+100 " " for total N and nitrates formed.
9	4—110 " "	+100 " " +5 gm. dext. for total N and NH_3 consumed.
10	4—110 " "	+50 " " KNO_3 for total N and nitrates consumed.
11	4—110 " "	+50 " " +5 gm. dextrose for total N and nitrates consumed.
12	4—100 " "	+10 c.c. of 10% casein solution for ammonification.

The entire set from 6 to 11 were weighed to hundredths of grams at the beginning and the end of the experiment. The difference at the end of the incubation period was taken as loss of moisture.†

† Dry weight.

† No correction made for loss of CO_2 .

†The object in taking the sample 8 inches was to go below the furrow slice so that after plowing, the number of bacteria in the sample would be approximately the same as it was before plowing.

*Moisture determinations made by spreading the soil thin and heating for two hours at 100°C.

**Optimum determined by experimentation, 23.5%.

Before the ammonia was determined the contents of each tumbler was put through an 8 mesh sieve, thoroughly mixed and 10* grams weighed out for total nitrogen determination.

Total nitrogen was determined by the Kjeldahl method modified to include nitrates and the results expressed as milligrams of nitrogen for 100 grams of soil. Ammonia was determined by MgO method and is expressed as milligrams N per 100 grams of soil. Nitrate determinations were made by reduction method[†] on extractions of 500 c.c. water to 100 grams soil shaken for one hour. The nitrates are expressed as milligrams of N per 100 grams soil.

*Approximate dry weight.

†Ann. Rept. Va. Polytec. Ins. Ag. Ex. Sta. 1911 and 1912, P. 137.

TABLE XVIII. GENERAL FARMING SOIL 6 DAY TEST ON AMMONIA CONSUMPTION. NITROGEN EXPRESSED AS MGM. OF NITROGEN PER 100 GRAMS DRY SOIL

Lab. No.	Previous Treatment	Special Treatment	NH ₃ Present at Beginning	NH ₃ Recovered	NO ₃ Present at Beginning	NO ₃ Present at End	NH ₃ Consumed	Date
6	General farming 2 weeks after harvest of wheat	No treat.	.90	1.1	2.3	2.15	0	8-28-13
6	"	No treat.	.85	1.2	2.3	2.15	0	"
7	"	100 mgm. of (NH ₄) ₂ SO ₄	23.22	15.6	2.3	2.60	7.3	"
7	"	"	23.22	17.1	2.3	2.70	5.8	"
9	"	100 mgm. of (NH ₄) ₂ SO ₄ + 5 gm. dext.	23.22	1.9	2.3	Not det.	21.3	"
9	"	"	23.22	1.7	2.3	"	21.5	"
6	8 weeks after wheat harvest	No treat.	1.30	1.0	1.9	2.05	.3	10-14-13
6	"	No treat.	1.90	.9	1.9	2.15	1.0	"
7	"	100 mgm. of (NH ₄) ₂ SO ₄	25.00	19.6	1.9	2.90	4.4	"
7	"	"	25.00	19.0	1.9	2.60	5.2	"
9	"	100 mgm. of (NH ₄) ₂ SO ₄ + 5 gm. dext.	25.00	2.1	1.9	Not det.	22.9	"
9	"	"	25.00	1.9	1.9	"	23.1	"

TABLE XIX. GENERAL FARMING SOIL, 6 DAY TESTS ON AMMONIA CONSUMPTION. NITROGEN EXPRESSED AS MGM. OF NITROGEN PER 100 GRAMS DRY SOIL

Lab. No.	Previous Treatment	Special Treatment	NH ₃ at Beginning	NH ₃ Recovered	NO ₃ at Beginning	NO ₃ at Close	NH ₃ Consumed	Date
6	1 week after plowing under wheat stubble and weeds	No treat.	1.1	1.6	.95	.85	0	11- 4-13
6	"	No treat.	1.7	1.30	.95	.85	0	"
7	"	100 mgm. of (NH ₄) ₂ SO ₄	24.1	11.60	.95	.9	12.5	"
7	"	"	24.1	9.90	.95	.8	14.2	"
9	"	100 mgm. of (NH ₄) ₂ SO ₄ + 5 gm. dext.	24.1	1.80	.95	Not det.	22.3	"
9	"	"	24.1	1.50	.95	"	22.6	"
6	5 weeks after plowing under wheat stubble and weeds	No treat.	1.9	1.65	1.04	1.1	0	12- 9-13
6	"	No treat.	1.4	1.65	1.04	1.1	0	"
7	"	100 mgm. of (NH ₄) ₂ SO ₄	26.3	11.60	1.04	1.1	14.6	"
7	"	"	26.3	12.00	1.04	1.1	14.2	"
9	"	100 mgm. of (NH ₄) ₂ SO ₄ + 5 gm. dext.	26.3	3.20	1.04	Not det.	23.1	"
9	"	"	3.0	3.00	1.04	"	23.3	"

TABLE XX. AMMONIFICATION TESTS USING CASEIN, INCUBATED FOR 6 DAYS ON GENERAL FIELD SOILS. NITROGEN EXPRESSED AS MGM. PER 100 GRAMS DRY SOIL

Lab. No.	Treatment	Special Treatment	Ammonia Found	Date
12	2 weeks after wheat harvest	10 c.c. of 10% casein solution	40.17	8-28-13
12	"	"	41.09	"
12	8 weeks after wheat harvest	"	36.95	10-14-13
12	"	"	35.89	"
12	1 week after plowing under wheat stubble	"	28.16	11- 4-13
12	"	"	29.36	"
12	5 weeks after plowing under wheat stubble	"	31.47	12- 9-13
12	"	"	32.00	"

TABLE XXI. GENERAL FARMING SOIL, 6 DAY TEST ON NITRATE CONSUMPTION NITROGEN EXPRESSED AS MGM. OF N PER 100 GRAMS DRY SOIL

Lab. No.	Previous Treatment	Special Treatment	NO ₃ at Beginning	NO ₃ at Close	NO ₃ Consumed	Date
3	2 weeks after harvest	Immediate analysis for NO ₃	2.3			8-28-16
3	"	"	2.3			"
8	"	100 mgm. of (NH ₄) ₂ SO ₄	2.3	2.15		"
8	"	"	2.3	2.15		"
10	"	50 mgm. of KNO ₃	9.3	5.20	4.10	"
10	"	"	9.3	5.70	3.60	"
11	"	50 mgm. of KNO ₃ + 5 gm. dextrose		1.30	8.0	"
11	"	"	"	1.40	7.90	"
3	8 weeks after wheat harvest	Immediate analysis	1.9			10-14-13
3	"	"	1.9			"
8	"	100 mgm. of (NH ₄) ₂ SO ₄	1.9	2.05		"
8	"	"	1.9	2.05		"
10	"	50 mgm. of KNO ₃	8.1	6.45	1.54	"
10	"	"	8.1	7.13	.86	"
11	"	50 mgm. of KNO ₃ + 5 gm. dextrose	8.1	2.01	5.98	"
11	"	"	8.1	1.96	6.18	"

TABLE XXII. GENERAL FARMING SOIL, 6 DAY TEST NITRATE CONSUMPTION.
NITROGEN EXPRESSED AS MGM. OF N PER 100 GRAMS DRY SOIL

Lab. No.	Previous Treatment	Special Treatment	NO ₃ at Beginning	NO ₃ at Close	NO ₃ Consumed	Date
3	1 week of plowing under wheat stubble	Immediate analysis	.95			11- 4-13
3	"	"	.95			"
8	"	100 mgm. of (NH ₄) ₂ SO ₄	.95	.91		"
8	"	"	.95	.87		"
10	"	50 mgm. of KNO ₃	8.89	4.61	4.28	"
10	"	"	8.89	4.00	4.89	"
11	"	50 mgm. of KNO ₃ + 5 gm. dextrose	8.89	.99	7.90	"
11	"	"	8.89	1.12	7.77	"
3	5 weeks after plowing under wheat stubble	Immediate analysis	1.00			12- 9-13
3	"	"	1.09			"
8	"	100 mgm. of (NH ₄) ₂ SO ₄	1.09	1.07		"
8	"	"	1.09	1.23		"
10	"	50 mgm. of KNO ₃	9.10	5.23	3.76	"
10	"	"	9.10	4.98	4.01	"
11	"	50 mgm. KNO ₃ + 5 gm. dextrose	9.10	1.71	7.28	"
11	"	"	9.10	1.68	7.31	"

The preceding tables on ammonia and nitrate consumption by soils from the general farming section shows distinctly that the soil in question has an inherent ability to consume definite quantities of ammonia and nitrates which is similar to the biological absorption (33) of phosphates. The inherent capacity for ammonia consumption in these soils is greater in every instance than the nitrate consumption. There is an increase of ammonia and nitrate consumption after plowing under wheat stubble (and weeds). The addition of dextrose increased the consumption of nitrates and ammonia practically to the limit of exhaustion. This, latter, has no particular significance aside from the fact that the soil flora consumes considerable quantities of either ammonia or nitrate in the presence of suitable sources of energy.

For the sake of brevity, the following tables have been compiled from work on soils which were treated with large quantities of straw and are given to show the comparative effect of applications of large quantities of straw on ammonia and nitrate consumption and ammonification. The plots had grown oats the previous season and had been kept free from weeds. The method of treating the plots in question was as follows: Finely chopped wheat straw (pieces about 1 cm. long) was applied at the rate of 20 tons per acre and turned under with a spade arranged so that it would not go deeper than 6 inches. The straw was applied and spaded under every year in October. The plots were planted to wheat the following spring.

The method of sampling and laboratory procedure was the same as previously described for the general field, but for the sake of comparison all data excepting actual ammonia and nitrates consumed and ammonia formed has been eliminated. The plot receiving no straw is numbered 1, and the one receiving straw is numbered 2.

TABLE XXIII. COMPARISON OF AMMONIA CONSUMPTION, NITRATE CONSUMPTION, AND OF AMMONIA FORMATION FROM CASEIN, ON PLOTS TREATED WITH STRAW AND ONES NOT RECEIVING STRAW, EXCEPT STUBBLE. NITROGEN EXPRESSED AS MGM. OF N. PER 100 GRAMS DRY SOIL

Plot No.	Field Treatment	Special Lab. Treatment	NH ₃ Consumed	NO ₃ Consumed	NH ₃ Liberated from Casein	Date
1	Oat stubble 3 weeks after harvest	Nothing	10.63	4.96	40.57	9- 2-14
1	"	5 gm. dextrose	21.33	7.79	Not determined	"
2	"	Nothing	10.90	4.68	41.11	"
2	"	5 gm. dextrose	20.46	7.23	Not determined	"
1	Oat stubble 5 weeks after harvest	Nothing	10.00	5.71	42.66	9-15-14
1	"	5 gm. dextrose	20.33	8.19	Not determined	"
2	"	Nothing	11.13	4.32	41.17	"
2	"	5 gm. dextrose	20.91	7.11	Not determined	"
1	Oat stubble 8 weeks after harvest	Nothing	9.42	4.46	42.49	9-29-14
1	"	5 gm. dextrose	20.73	9.01	Not determined	"
2	"	Nothing	12.01	4.99	43.68	"
2	"	5 gm. dextrose	21.10	8.86	Not determined	"
1	One week after turning under oat stubble	Nothing	10.59	5.14	39.33	10-15-14
1	"	5 gm. dextrose	21.96	8.26	Not determined	"
2	1 week after turning under oat stubble and finely chopped wheat straw at rate of 20 tons per acre.	Nothing	17.63	6.99	31.17	"
2	"	5 gm. dextrose	21.83	8.87	Not determined	"
1	3 weeks after plowing under oat stubble	Nothing	11.01	5.26	38.22	10-28-14
1	"	5 gm. dextrose	20.44	9.75	Not determined	"
2	3 weeks after turning under oat stubble and 20 tons of wheat straw per acre	Nothing	19.72	8.92	26.91	10-28-14
2	"	5 gm. dextrose	22.00	9.11	Not determined	"

The results recorded in Table XXIII are averages of duplicate determinations. In calculating the ammonia and nitrate consumed and the ammonia formed, corrections were made for the amounts of ammonia or nitrates in the soil at the beginning and close of the experiment. The results in Table XXIII show that these soils have an inherent ammonia and nitrate consuming power. The amount of ammonia or nitrates consumed is increased slightly by turning under oat stubble and markedly increased by turning under 20 tons of finely chopped straw per acre. At the same time, it will be noticed that the application of dextrose at the rate of 5 grams per 100 grams of soil greatly increased the amount of ammonia and nitrates consumed where the quantity of straw is small, but does not show such a marked increase where straw was added in large quantities, indicating that the straw added furnished almost enough energy to allow the consumption (compare references 25, 26, 27, 28) of almost all the ammonia and nitrates in the soil. It does not follow that the straw was used in preference to dextrose as a source of energy. In most instances, the reverse would be true. Plowing under oat stubble slightly decreased the ammonifying power of the soil, while the

application of 20 tons of straw per acre reduced the ammonifying power from 26 to 36 percent. This amount of straw would seldom, if ever be added under practical conditions, but it was added in the present instance in order to magnify the ammonia and nitrate consumption as well as to determine the retarding effect upon ammonification so as to emphasize the principle involved.

If the weight on an acre foot of the above soil be taken at 2,500,000 pounds and 20 tons of straw was mixed with 8/12* of an acre foot, it would be equivalent to adding approximately 2 grams of straw per 100 grams of soil. Therefore, in order to check the above results, soil was secured from plot 1 and thoroughly mixed with finely chopped wheat straw at the rate of 2 grams per 100 grams of soil. Ammonia and nitrate consumption tests of the treated soil were then made by the beaker method. The results are recorded in Table XXIII.

TABLE XXIV. CONSUMPTION OF AMMONIA IN 100 GRAM PORTIONS OF SOIL CONTAINING 2 GRAMS OF FINELY CHOPPED STRAW PER 100 GRAMS. NITROGEN EXPRESSED AS MGM. OF NITROGEN PER 100 GRAMS SOIL INCUBATION PERIOD: 7 DAYS

No.	Amt. of Soil gm.	Ammonia added	Ammonia consumed	Inherent ammonia consuming power	Ammonia consumption due to straw
1	100	19.28	8.3	2.5	5.6
2	100	19.28	7.4	2.5	5.9
3	100	19.28	7.4	2.5	5.9
4	100	19.28	8.6	2.5	6.1
5	100	19.28	6.8	2.5	4.3
6	100	19.28	6.8	2.5	4.3

In Table XXIV, we have the results of 6 tests on ammonia consumption in soils to which finely chopped straw has been added at the rate of approximately 20 tons per acre. The results are so definite that comments are hardly necessary. The ammonia consuming power of the untreated soil was 2.5 mgm. Ammonia determined by the aeration method (55).

It has been suggested in the preceding pages that ammonification is an expression of an unbalanced bacterial medium in which the nitrogen of the organic matter was in excess of the bacterial food requirements. This assumption was due to the results obtained in ammonification tests and ammonia consumption tests where the energy material was in excess. One would therefore be inclined to assume that ammonification was an expression of an unbalanced bacterial medium in which the nitrogen was in excess of the available energy material. It is possible, however, that another food constituents might at times be the factor limiting the accumulation of ammonia. Furthermore, certain results previously mentioned lead to the assumption that available plant food constituents were also the food constituents of microorganisms that were in excess of the nutrient energy ratio of the microorganisms. These two statements, while

*Samples were taken to a depth of eight inches and mixed thoroughly. Therefore, it is equivalent to adding the straw to 8/12 of an acre foot.

TABLE XXV. THE EFFECT OF INCREASING QUANTITIES OF PHOSPHATES ON AMMONIFICATION OF CASEIN BY *B. MYCOIDES*. 6 DAY TEST.

Lab. No.	c.c. of 1/1000 Mono-Phos.	Inoculation	Mgm. of ammonia formed	Million of bacteria per c.c.
0*	None	None	None	-
1	Casein and distilled water only	1 c.c. of 72 hr. culture <i>B. mycoides</i>	"	No growth
2	"	"	"	" "
3	All nutrients except P	"	5.4	7.5
4	"	"	4.9	6.1
5	All nutrients + .1 c.c. P	"	6.4	9.2
6	"	"	6.1	9.4
7	All nutrients + .2 c.c. P	"	7.8	10.1
8	"	"	7.0	9.7
9	All nutrients + .3 c.c. P	"	9.2	12.
10	"	"	8.7	10.6
11	All nutrients + .4 c.c. P	"	8.2	11.0
12	"	"	9.9	13.0
13	All nutrients + .5 c.c. P	"	10.0	13.3
14	"	"	11.2	14.9
15	All nutrients + 1 c.c. P	"	15.7	17.2
16	"	"	16.9	17.6

* Residual ammonia determination, not inoculated.

supplementing each other, are apt to leave the impression that the amount of ammonification and liberation of the concomitant available plant food constituents are solely dependent upon the amount of energy material. Such is not of necessity the case. There may be a medium in which there is an excess of nitrogen over energy and obtain only a limited evolution of ammonia because some other element necessary for bacterial development was present in very small quantities. To test this view and thus accredit the other necessary elements, their proportions of influence, 5 liters of a medium was made up conforming in every way to medium No. 2, with the exception of phosphorus and potassium. This medium was then divided in half and one half received the required amount of potassium and measured out in 100 c.c. portions and placed in 500 c.c. non-sol erlenmeyer flasks. Four 100 c.c. portions of a medium containing casein only were inoculated as controls. These were checked by four 100 c.c. portions containing casein and all nutrients excepting phosphorus as controls for the phosphorus in the casein. Four other 100 c.c. portions were labelled for residual ammonia determinations. 12 of the flasks containing 100 c.c. portions of the medium were arranged in a series to test the effect of increasing quantities of phosphorus. The phosphorus was added as follows: To the first two flasks .1 c.c. each of 1 to 1000* phosphate solution. To the second two flasks .2 c.c. and so on up to .5 c.c. The two remaining flasks received 1 c.c. each of the phosphate solution. The potassium series after receiving the proper amount of phosphorus, were treated in a similar manner, receiving .1 c.c. .2 c.c., etc., up to 1 c.c. The two remaining set of duplicates in the series received respectively 1.5 c.c. and 2 c.c. The entire set of flasks were then sterilized in the autoclav at 10 pounds for 15 minutes.

*One gram of Ca (H_2PO_4)₂ in 1000 c.c. distilled water.

TABLE XXVI. SIX DAY TEST ON EFFECT OF INCREASING QUANTITIES OF POTASSIUM SULPHATE UPON THE AMMONIFICATION OF CASEIN BY *B. MYCOIDES*

Lab. No.	c.c. of 1/1000 K ₂ SO ₄	Inoculation	Mgm. of NH ₃ produced	Millions of bacteria per c.c.
1	All nutrients except K	1 c.c. of 72 hr. culture of <i>B. mycoides</i>	None	None
2	"	"	"	"
3	All nutrients +.1 c.c. K	"	0.	"
4	"	"	0.	"
5	All nutrients +.2 c.c. K	"	1.5	4.7
6	"	"	1.9	4.0
7	All nutrients +.3 c.c. K	"	4.3	5.6
8	"	"	4.0	4.0
9	All nutrients +.4 c.c. K	"	7.1	8.0
10	"	"	7.3	7.9
11	All nutrients +.5 c.c. K	"	10.7	11.2
12	"	"	11.1	13.1
13	All nutrients +.6 c.c. K	"	11.0	13.3
14	"	"	12.2	13.8
15	All nutrients +.7 c.c. K	"	13.7	15.0
16	"	"	13.0	15.7
17	All nutrients +.8 c.c. K	"	14.8	18.2
18	"	"	14.6	19.0
19	All nutrients +.9 c.c. K	"	12.4	14.0
20	"	"	14.7	19.3
21	All nutrients + 1 c.c. K	"	14.8	20.6
22	"	"	14.7	21.1
23	All nutrients 1.5 c.c. K	"	14.8	22.0
24	"	"	15.0	24.5
25	All nutrients 2 c.c. K	"	14.9	23.8
26	"	"	14.8	24.7

After standing 72 hours, all of the flasks excepting those for residual ammonia were inoculated with 1 c.c. of a 72 hour culture of *B. mycoides*. The arrangement and results are given in the following tables. Ammonia determinations were made by the aeration method as developed by Lotter and Snyder (55). This method was tested by the addition of known amounts of ammonium sulphate to soils and solution and thus far has given satisfactory results.

Unfortunately the room temperature ranged from 22° to 23.5° C. during the period of incubation. Consequently, the amount of ammonia liberated during 6 days is comparatively low.

The previous assumption of the influence of other necessary constituents was based upon the probability that the liberation of nitrogen as ammonia comes about by reason of the organisms' effort to secure energy by oxidation of nitrogenous compounds. In other words the series of reactions by which the organisms left some ammonia nitrogen as an end product are not to be regarded as efforts to secure nitrogen but energy. Under the conditions of the foregoing experiment, the amount of energy required would not be governed by the amount of nitrogen present but by the amount of the limiting element. In one instance the limiting factor was phosphorus and in the other, potassium. In Table XXV, the amount of casein de-

composed for energy was governed by the amount of phosphorus present and in Table XXVI it was governed by the amount of potassium. As the nitrogen in the casein was in excess of the energy required by *B. mycoides*, the amount of ammonia left in the media was in the first instance proportional to the amount of phosphorus and in the second proportional to the potassium. On the other hand it is easy to see that if the energy had been in excess of the nitrogen, there would not have resulted any accumulation of ammonia with increased additions of phosphorus or potassium, but an increased bacterial number with ammonia nitrogen assimilated to the limit of availability.

It may therefore, be concluded that in the presence of abundant nutrients, the accumulation of ammonia from the decomposition of a nitrogenous compound which serves as a source of nitrogen will take place if the nitrogen-energy ratio of the medium is in excess of the nitrogen-energy ratio required by the organism. The amount of ammonia which will accumulate within the medium will approximate the amount which represents the nitrogen (liberated as NH_3) that was in excess of the nitrogen-energy ratio of the organisms. In the presence of a limited amount of one or more elements necessary for the development of the ammonifying organism, the amount of ammonia which will accumulate in a medium, whose nitrogen-energy ratio is in excess of the ratio of nitrogen to energy required by the organism, is proportional to the limiting food element. Conversely, if the energy-nitrogen ratio of the medium is equal to or in excess of the ratio of energy to nitrogen required by the organism, the amount of ammonia which accumulates within the medium will approximate the amount necessary for a concentration which represents an equilibrium between the rate of liberation and the rate of assimilation. If phosphorus or potassium or any other nutrient element is the limiting factor, the number of bacteria would be determined by the limiting element within a certain range, regardless of the energy nitrogen ratio.

The results of the previous experiment and particularly those recorded in Tables I, II, III, IV, VI, VII, XX, XXIII, XXV, XXVI lead the writer to believe that physiological activities, cannot be used to measure such function as are associated with multiplication of either pure (56) or mixed cultures (31). As pointed out by Hüne (67) the stimulating action of various poisons is clearly demonstrated by the directly increased intensity of cell division of the bacteria. By means of the plate method he was able to obtain exact comparative values, between the stimulating action and the increased cell division, and thereby established the correctness of Arndt's law, even for microorganisms. Such a course should be followed in determining the depressing effect of various anions and cations (56), as well as when determining the effect of any other agents (31) upon bacterial increase, or decrease and not by measuring the effects of such agents by variable physiological phenomena.

Furthermore, the increase of ammonification due to the application of phosphates, as noted by Lipman and associates (16) (Bull. 246, P. 34), Fred and Hart (19) (P. 54) due to the application of a sulphate and to the increase in the number of bacteria caused by

the application of a phosphate, as noted by Fred and Hart, and also by Stoklasa (as cited by Fred and Hart (19) P. 53 and McLean and Wilson (17) confirm the results in Tables XXV and XXVI. These results, as well as those in the references cited, are probably due to the addition of a nutrient element or elements that is present in the medium in limiting quantities. Such a conclusion does not exclude the influence that such elements as calcium or magnesium, etc., would have in correcting the reaction of the medium or the detrimental effect of too large a quantity of material.

The addition of soluble nutrients, such as phosphates, nitrogen, potassium, etc., to an unbalanced bacterial medium (organic matter, soils, etc.) increases the number of microorganisms in that medium as long as the number remains below the possible maximum. The greater number of microorganisms causes an increased decomposition of organic matter. Increased decomposition of organic matter usually causes an increased evolution of CO_2 . The evolution of CO_2 indicates a narrowing of the ratio of energy to nutrients. The more rapid the evolution of CO_2 for any given set of conditions, the sooner the point is reached where the readily available energy falls below the amount required for the energy nutrient ratio of the flora, and consequently the point at which the excess nutrients begin to accumulate as available plant food. When the ratio of energy to nutrients becomes too low, bacterial numbers decline. This is illustrated by the bacterial counts given in Tables XIII, to XVII and by the comparative low counts from continuously cropped clover (23) lands.

The method employed in arranging and explaining the data presented in this bulletin has been such as to emphasize the direct action of soil microorganisms upon organic matter of the soil. Likewise the assimilation of the water soluble plant food constituents in the presence of energy material and the final liberation of available plant food from the organic matter of the soil after the ratio of energy to nutrients has fallen below the amount required by the soil flora is also pointed out. No data has been presented which should weaken the conception of the indirect action of microorganisms upon the insoluble mineral constituents of the soil. The solvent action, of organic acids liberated by the decay of the organic matter and such acids as may arise from purely chemical changes, goes hand in hand with the liberation of the acids. It is possible that in normal soils where the organic content is not excessive that the neutralization of the acids by a base precedes the utilization of the acid* for energy, at least as far as the actions of bacteria are concerned.

That the solvent action of these soil acids plays no small part has been demonstrated by numerous chemical experiments. The pot work of Clinton and Merrill and the field tests of several years duration of Dyer, Johnson, Goesman, Hess, Jordan, Newman, Newman and Clayton, Lufton, Wheeler, Patterson and Thorne upon the use of rock phosphate, as cited by Tottingham and Hoffman (40), have shown the value of rock phosphate as a fertilizer, particularly when used with organic matter.

*Carbonic acid which does not represent available energy, does not enter into this phase.

The experiments of Stoklasa (38), Koch and Krober (57) and Sackett and associates (58) show the indirect action of bacteria in making soluble the phosphates from insoluble compounds, while the recent valuable contributions of Hopkins and Aumer (59) shows in a very decided and conclusive manner that potassium can be obtained from the so-called "insoluble residue" of soils. This work of Hopkins and Aumer demonstrates also the influence of organic matter upon the liberation of plant food constituents from the insoluble mineral particles of the soil. Hopkins and Aumer, speaking of the purpose of the work say: "the chief purpose of the investigations reported in this bulletin was to secure information as to the power of decaying organic matter to liberate potassium from the soils abundant supply".

It may be concluded that the relation of microorganisms (bacteria) to available plant food may be best explained by adding two steps in the process. First, the more or less complete assimilation of plant food in the presence of excess energy material and, second, the accumulation of available plant food from the organic matter and by the action of acids upon the insoluble mineral particles of the soil after the excess energy material has been exhausted.

The addition of organic matter high in energy material results in an immense increase in the microorganisms which assimilate considerable quantities of available plant food. The number of microorganisms involved in the decay of the organic matter may at times be governed by the soluble form of the limiting food element being practically exhausted or by limited energy material or physical or chemical factors. A solvent action of acids* liberated from the decaying organic matter occurs simultaneously with the assimilation of available plant food. The acids thus liberated may be neutralized wholly, or in part, by excess ammonia, alkaloids, or excess basic ions freed from the decaying organic matter and by the basic ions obtained by the reaction of the acids with the insoluble mineral particles of the soil. In the presence of excess available energy, the basic plant food elements, neutralized by the acids, may be immediately assimilated wholly***, or in part, by the microorganisms. After the proportions of excess energy has fallen below the energy nutrient ratio required by the soil flora, the nutrient elements in excess of the microorganisms requirements begin to accumulate within the soil. The organic acids formed simultaneously with the liberation of available plant food elements thru the decay of organic matter acts upon the insoluble mineral particles making available some of the plant food constituents within the soil grains. The plant food constituents liberated from the organic matter after the excess energy has disappeared and those liberated by the action of acids upon the soil grains after the excess energy has disappeared becomes available to plants.

*Amino acids as well as the lower fatty acids.

***In this connection, note the comments of Tottingham and Hoffman comparing the conclusions of Stoklasa with those of Serverin.—Bibliography 32, p 296.

SUMMARY

Bacterium mycoides, *B. subtilis*, *B. megatherium*, *B. vulgatus*, *B. proteus* and *Sarcina lutea* can assimilate ammonia from ammonium sulphate when dextrose is present as a source of energy and carbon.

The depressing effect of dextrose upon the ammonification of casein in a nutrient synthetic solution by pure cultures of *B. mycoides*, *B. subtilis*, *B. megatherium*, *B. vulgatus*, *B. proteus* and *Sarcina lutea* is due largely to dextrose serving as a source of energy, thereby allowing the above organism to consume some of the ammonia liberated by them from casein.

The presence of dextrose does not inhibit the multiplication of these organisms in the casein solution, but it sometimes may lessen the amount of casein decomposed and the amount of ammonia which accumulates because the organism can utilize the ammonia as a source of nitrogen and dextrose as a source of energy. The same effect probably takes place when dextrose or other energy material is added to soils.

These six "ammonifying" bacteria in a synthetic solution containing dextrose and all necessary plant food elements and ammonia of ammonium sulphate as a source of nitrogen can successfully compete with maize seedling for the plant food elements when grown in quartz sand containing 12% moisture and maintained under conditions which exclude other organisms.

When casein is substituted for the ammonium sulphate in the medium containing dextrose, *B. mycoides*, reduces the final weight of maize seedlings.

When potassium nitrate is substituted for ammonium sulphate, under the above conditions, *B. megatherium* reduces the final weight of maize seedlings.

Within the limits of these experiments, the presence of 1 gram of dextrose in 1 liter of the above synthetic solution does not measurably lessen the growth of maize seedlings. One tenth gram of ammonium sulphate in 1 liter of the above synthetic solution did not prove toxic to maize seedlings.

Under the conditions of the experiment, the difference in growth of maize seedlings in the presence and absence of dextrose may be attributed almost wholly to the competitive action of the bacteria. The presence of available energy material enables bacteria (microorganisms) to assimilate available plant food and thereby compete with plants.

The terms "beneficial" and "detrimental" bacteria when applied to saprophytic organisms have only a relative value. Under a certain proportion of energy to nutrients, the beneficial organism may become "detrimental" and vice versa.

Oats grown in pots containing quartz sand are greatly reduced in yield when dextrose is added in the presence of limited amounts of plant food. When dextrose is added in the presence of abundant plant food, the reduction in oat yield is much less. The reduction of oat yield when dextrose is added with limited amounts of plant food is due largely to the competitive action of microorganisms and partly to the unfavorable condition created either by dextrose or

the decomposition products of dextrose. When dextrose is added with excess plant food, the reduction of oat yield may be due either wholly to the action of the dextrose and its products or to excess of other plant food elements, such as KNO_3 or $(\text{NH}_4)_2\text{SO}_4$.

Soils have a definite ammonia and nitrate consuming power. The addition of dextrose or straw temporarily increase it. When large quantities of straw (20 tons per acre) are added to soils, there is a marked decrease in the ammonifying power and a marked increasing in the ammonia and nitrate consuming power. Plowing under crop residues affects the soil in a similar way, but to a less extent. The disturbing influence of organic residue is largely due to the excess energy material which causes a marked temporary increase in multiplication of microorganisms and a proportional assimilation of plant food elements followed upon exhaustion of the excess energy material, by an increased liberation of plant food.

Within certain limits, the number of bacteria and the ammonification of casein in a synthetic solution by *B. mycoides*, is proportional to the quantity of phosphorus or potassium added when the phosphorus or potassium is present only in limited amounts.

The flora, the energy-nitrogen ratio and the stage of decomposition must be fixed before a constant relation will hold for total numbers of microorganisms and a soil's ammonifying power. This conclusion practically eliminates the so-called "ammonifying power" as an index to soil fertility.

Ammonification should be defined as that process in which the nitrogen; of the organic matter, that is in excess of the energy-nitrogen ratio of the ammonifying organism, is liberated as ammonia.

There probably is a relation between the ammonifying power of an organism and its energy-nitrogen ratio. A nitrogenous compound or compounds, capable of ammonification, having a high proportion of available energy material to nitrogen, has a low ammonifiable coefficient and one with a low proportion of available energy material to nitrogen has a high ammonifiable coefficient. There probably is a relation between the ammonifying power of mixed cultures and the sum of their energy-nitrogen ratios.

Ammonification is an expression of an unbalanced ration for microorganism in which the nitrogen is in excess of the energy-nitrogen ratio.

For a certain length of time the ammonifying coefficient tends to approach zero, if the available energy material is equal to or in excess of the energy-nitrogen ratio of the flora, and will tend to approach the maximum if the available energy material is less than the energy-nitrogen ratio. The shortage or absence of other nutrients does not materially affect the ammonifying coefficient. but does affect the quantity of ammonia which accumulates within a medium.

The competition of microorganisms for plant food constituents is at its maximum when there is excess available energy material at their disposal and approaches a minimum as the available energy material falls below the energy nutrient ratio. To a certain extent, the reverse is true of the accumulation of plant food constituents.

A point may be reached when the liberation and accumulation of plant food constituents is retarded if the proportion of available energy material to nutrients falls too low. This may take place in decomposed manures or in the organic matter of cultivated soils to which organic matter has not been added for some time.

The addition of organic matter, high in available energy material, may temporarily retard nitrification first by the assimilation of ammonia by the decay microorganisms, second by the assimilation of the nitrates.

Molds, most probably, play an important part in the aerobic decomposition processes of the soil. They are active in the assimilation of plant food constituents during the first stage of decomposition of crop residues and later may play just as important a part as the bacteria in liberating plant food constituents. Yeasts and algae are not necessarily insignificant factors.

The cellulose decomposing bacteria and molds unquestionably exact toll from the soluble plant food constituents to build cell substance while obtaining energy from the cellulose and incidentally convert the cellulose into forms available to other organisms.

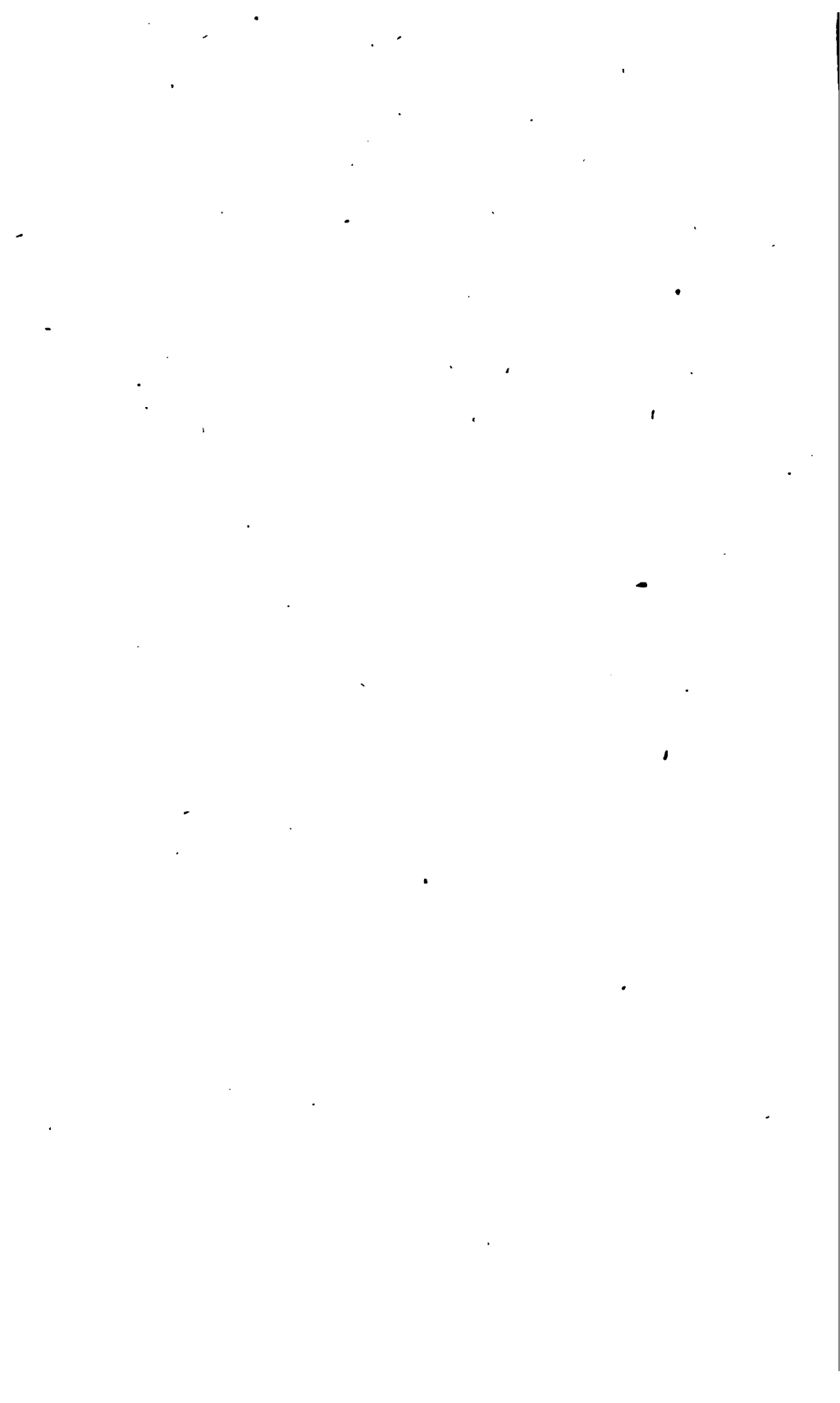
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Agricultural Experiment Station

Composition of the Maize Plant

By J. W. Iace

Bulletin No. 117

Agricultural College, North Dakota
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J. W. INCE, A. M., Soils (Chemistry).
ROBT. HULBERT, B. S., Microscopy.
W. F. WASHBURN, M. S., Paints.
ADELE SHEPPERD, Waters.
*LEVI THOMAS, M. S., Asst. Chemist (Baking).
THOMAS SANDERSON, Miller.
H. O. WERNER, B. S., Assistant Horticulturist.
LEUNIS VAN ES., M. D., V. S., Veterinarian.
JAMES E. BOYLE, Ph. D., Investigation in Agricultural Economics.
O. A. THOMPSON, B. S., Superintendent of Edgeley Substation.
*JOHN THYSELL, B. S., Superintendent of Dickinson Substation.
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*A. J. OGAARD, B. S., Superintendent of Hettinger Substation.
W. R. PORTER, M. S. A., Superintendent of Demonstration Farms.
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COMPOSITION OF THE MAIZE PLANT

By J. W. Ince

During the past two years, 1914 and 1915, a project was carried on by the North Dakota Experiment Station for determining the yield of mineral matter and organic constituents of the maize plant under North Dakota conditions. The object of these trials was to test corn at a number of stages in its development to ascertain the increase in food value of the plant for the several periods of growth and the best stage for cutting corn for silage. The stages selected were when the corn was in tassel, in milk, in the dough, when glazed and when fully ripe. In 1914 the trials were carried on at the Central Experiment Station and the sub-stations located at Dickinson, Edgeley and Williston. In 1915 the trials were limited to the central station. The varieties used were considered satisfactory for each respective region, at Dickinson and Williston, Northwestern dent, at Edgeley, Minnesota No. 23 and at the Experiment Station, Mercer flint.

It is important to note the climatic conditions under which the corn was grown, not only because this plant responds directly to climatic factors, but also because of the particular interest attached at the present time to the culture of corn in North Dakota. The following meteorological observations, made at this Experiment Station, are available for such a study. The total annual rainfall for both 1914 and 1915 was approximately the same, 16.52 and 16.93 inches respectively, but less than the average for a twenty year period (1893-1913), namely 20.25 inches. The total rainfall for the growing period, May to October inclusive, was practically the same in both years, 14.11 for 1914 and 14.47 inches for 1915, but again less than the average for the twenty years above mentioned, 16.23 inches. The distribution of the rainfall during the summer months of both these years fluctuated from the normal in about the same degree though the greatest variation between the two years occurred in May, July and August; in 1914 an excess of rain occurring in July and August, and in 1915 an excess in May. Generally speaking, however, the precipitation was practically the same in both 1914 and 1915 but slightly less than the normal. This information is shown in detail in Table I and Chart I in which the total annual rainfall and the rainfall for the months May to October are compared with the average conditions of a period of twenty years.

The year 1914 was warmer than the average with the single exception of August when the difference was less than one degree. The year 1915 was below normal temperature except for September and October. In other words the mean daily temperature of the growing period was slightly different from that of the twenty year period studied, 1914 being nearly four degrees higher and 1915 one degree lower than the average. It is interesting to note that July 1914 was the warmest month on record for the twenty two years considered in this data. The months of September and October were

warmer for both years than the normal. This at least partially explains the favorable late growing weather afforded the corn for these two years. The detailed data is given in Table I and Chart II.

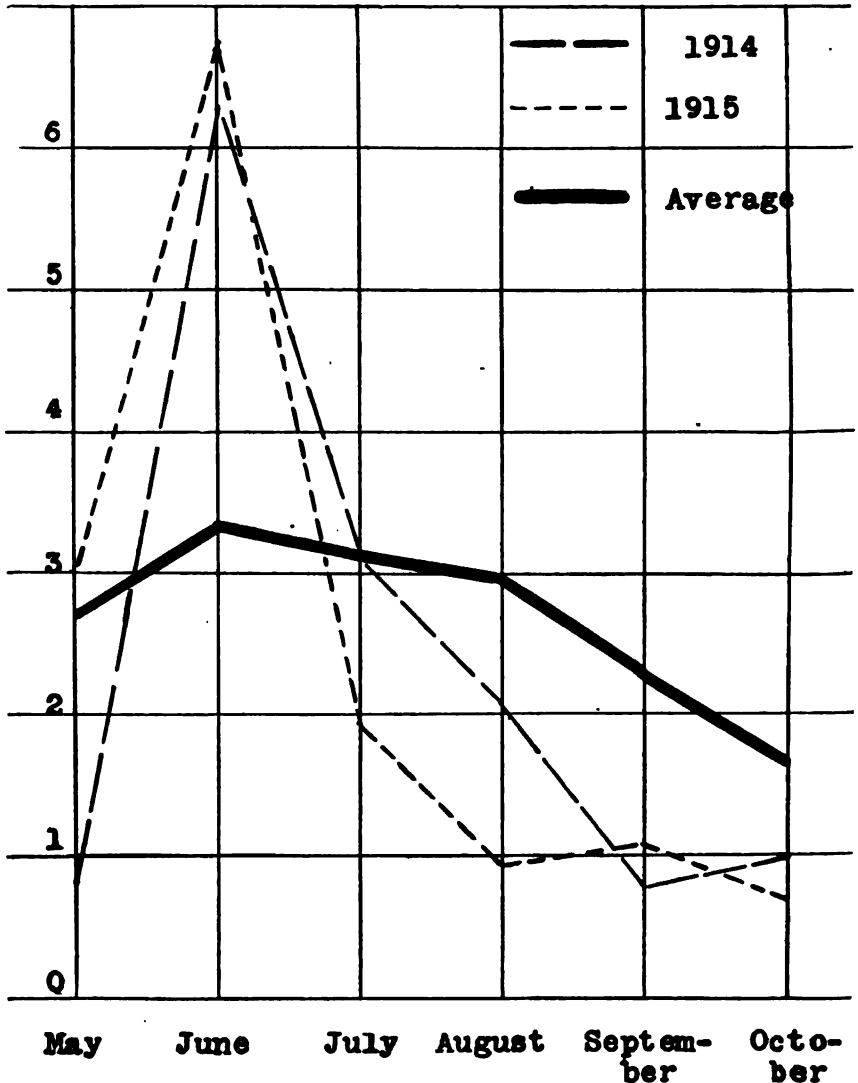


Chart I. Rainfall (inches).

There is considerable difference in the sunshine record for 1914 and 1915 (Chart III) and some variation from the average. Excepting September, there was more sunshine in 1915 than normal. There was more or less fluctuation in 1914, half the months being below normal and half above. With the exception of October 1912 there was more sunshine recorded during October 1914 than for any other October

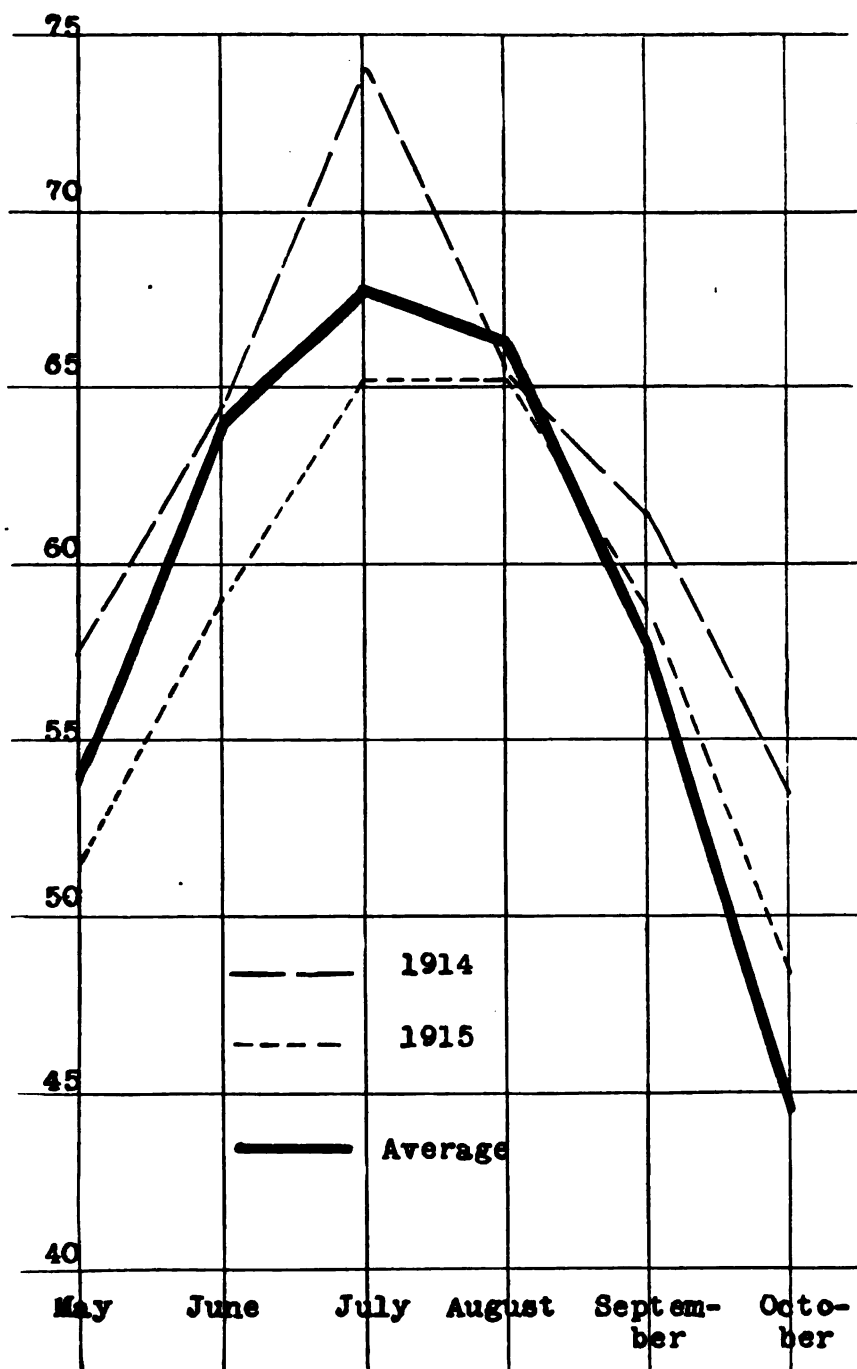


Chart II. Mean daily temperature.

in the years studied. The first killing frosts for 1914 were October 14, 29°, and October 26, 23°; and for 1915 were on October 8, 24°, and October 20, 27°.

Inasmuch as the season of 1915 was very unfavorable for the growth of corn it might be well in this connection to cite the results of a special inquiry made for this year by the U. S. Bureau of Crop Estimates in regard to the maturity of corn for this and other states. A condensed statement of their findings is given in the Monthly Report for December 30, 1915, from which the following table was taken.

MATURITY OF CORN CROP, 1915 AND USUAL YEAR

State	Fully matured		Dough stage		Milk stage		Before milk stage	
	1915	Usual year	1915	Usual year	1915	Usual year	1915	Usual year
Indiana	80	93	16	6	4	1	0	0
Illinois	68	92	22	7	8	1	2	0
Michigan	35	87	42	10	16	2	7	1
Minnesota	10	86	44	10	32	3	14	1
Wisconsin	10	88	44	12	32	4	14	1
Iowa	25	88	42	10	24	2	9	0
Missouri	93	98	7	2	0	0	0	0
North Dakota	8	60	35	25	32	10	25	5
South Dakota	26	84	34	11	30	5	10	0
Nebraska	47	93	36	7	14	0	3	0
Averages for 10 States shown	51	91	29	8	15	2	5	0
Averages for entire crop	72	95	17	4	8	1	3	0

The amount of fully matured corn in North Dakota was only about one-eighth of that of the usual year. On the other hand, when comparing this with the figures for Wisconsin and Minnesota, the amount of fully matured corn was about the same proportion of the usual percentage so that in this respect this state was in no worse condition than the other two. As would be expected, the percentage of fully matured corn in the usual year is lower for North Dakota than for the other states listed. This fact all the more emphasizes the importance of the data involved in this investigation, namely, that special effort must be made towards securing acclimated early maturing strains of corn for this state.

In general, then, the rainfall for both 1914 and 1915 was less than the normal, the growing season of 1914 warmer than usual and 1915 cooler than usual. The period of sunshine for 1914 was below normal and for 1915 above normal. The rainfall for these two years was the same; the temperature and sunshine were different; and there was apparently no relation between the last two factors. Due to unfavorable growing conditions there was less corn maturing in 1915 in the middle northern states than in the average year and North Dakota was one of the states affected by this condition.

In 1914 the crop was grown in hills and was given good cultivation and good general conditions. On the several dates for testing the corn, a measured area equivalent to one-tenth or one-fifth acre, representing the average condition of the field for each period, was carefully cut and weighed. Such a fraction of an acre served as a

basis for obtaining the yield of the corn per acre. Three smaller portions, each one rod square, were cut out of the larger area, weighed separately and field cured. Later the sample which was the

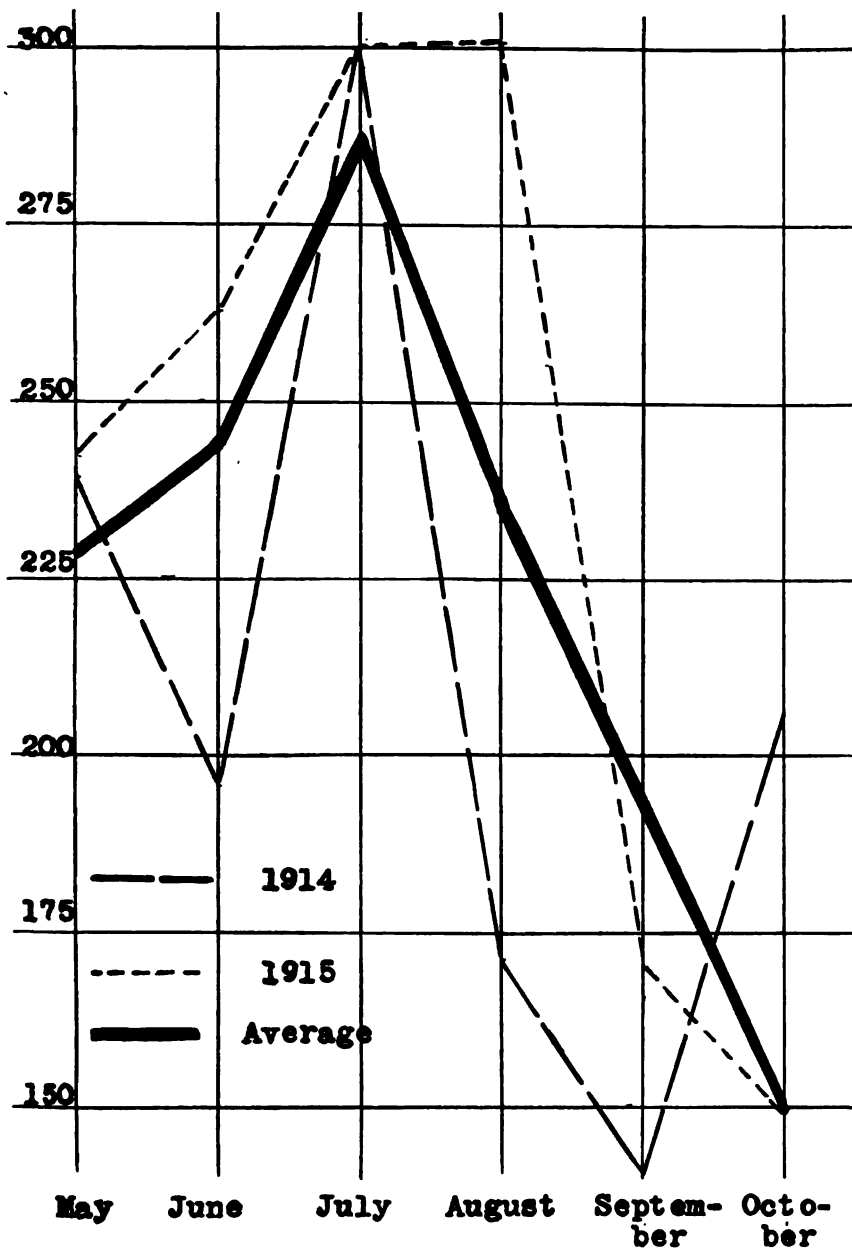


Chart III. Sunshine (hours)

average in weight and general conditions was sent to the chemical laboratory of the experiment station for analysis. Ears of corn, in most cases, were carefully removed, weighed and analyzed separately.

For the analysis of the corn samples the methods of the Official Agricultural Chemists were used in making the different determinations, all analyses being made in duplicate. In 1914 two sets of analyses were made, namely, upon the complete plant and the ears, that is the cobs and kernels. In 1915 the stalks, blades and husks were analyzed together, and the ears, that is cobs and kernels, were



Fig. 1.—Corn at first cutting.

analyzed separately and the data from these two sets of analyses computed for the complete plant. This was the only difference in method of procedure in the two years. In both cases the stalks and ears were cut up separately in a fodder cutter. The corn was cut in the field about two or three inches above the surface of the ground.

A comparison of the samples selected for analysis in 1915 with the larger cuttings made for yields indicated that there was an unconscious tendency to partly favor the analytical samples. While the average number of stalks per hill and the average weight per

hill of the selected samples was greater than for the average of the larger area, the average weight per stalk was less. This may mean that the more luxuriant looking hills were selected by the analyst, though every effort was made to be impartial and to secure samples which represented average conditions at the time they were taken. Other investigators have, however, had some difficulty in selecting samples of plants for analytical purposes, especially of corn which responds so much to local conditions.

In the 1914 trials the dates for harvesting the different stages of growth varied considerably at the different stations, the tasseled stage for example varying from July 11th to August 8th and the ripe stage from September 10th to October 16th, a variation of about one month in each case. In addition to this inequality of maturity at the different stations there is the added difficulty of each man selecting approximately equivalent stages, all of which points should be borne in mind when comparing results. And moreover there is the further possibility that the samples may have been either slightly under or over the stage desired.

FIELD DATA IN REGARD TO SAMPLES, 1914.

GROWN AT DICKINSON.

A destructive hail storm visited this station early in the season but it was decided to continue the trial. The leaves of the corn were badly split but the ears were developing and were handicapped only by the amount of crippling that the lacerated leaves represented. The land used in the trial was alfalfa sod broken in the spring to a depth of seven or eight inches and thoroughly disced and harrowed until planting time. The corn was planted May 15th, and appeared above the surface May 27th. It was harrowed on June 9th, and cultivated on June 17th and 23rd and July 14th. Some volunteer alfalfa came up after the last cultivation but not enough to materially hinder the growth of the corn.

GROWN AT WILLISTON.

The corn was planted May 30th and appeared above the ground June 8th. The field was cultivated June 9, 17, 24, July 6, 8, 27th, and August 4th. A light frost on August 26th tipped some of the leaves but apparently did not injure the corn.

GROWN AT CENTRAL EXPERIMENT STATION.

The ground was fall plowed, double disced on May 21st, and harrowed May 22nd. The corn was planted May 23rd. Later it was thinned down to three stalks per hill. The horse weeder was used June 6th and it was hand hoed on June 16th because of the recent rains which had been very heavy and had not drained away readily. This water standing upon part of the plot for some time may have caused an inequality in the maturing of the corn. This inequality was quite noticeable in the samples. The plot was cultivated June 24th, July 3, 7 and 16th.

The maximum green weight of the corn was the greatest at the dough stage, with the single exception of that grown at the Central Experiment Station. The maximum amount of dry matter appeared in the glazed stage at Edgeley and the Central Experiment Station and in the ripe stage at Williston. The percentage of dry matter in the corn shows a constant increase during the growth for all the



Fig. 2—Corn at cutting of September 18th.

localities. The different kinds of nutrient materials varied somewhat from one stage to another but not more than would be expected when the effects of the many factors involved are considered. When the average of the four trials for 1914 is considered it is found that the maximum green weight occurs at the dough stage, and the

maximum weight of dry matter at the ripe stage, though there is not much difference between that stage and the glazed. The nitrogen-free extract, or carbohydrates, reaches its maximum at the glazed stage though that amount is only very slightly greater than that for the ripe stage. The amount of ash is practically constant for all the stages except the tasseled. The detailed data giving the yields for these samples appears in Table II.

There is very little abnormal fluctuation shown in the analysis of the samples. As the crop matures the dry matter steadily increases and the constituents of this dry matter also tend to increase in amount. This was true in the case of nearly every constituent studied in these samples. For example the summary of the 1914 analyses upon the original basis (Table III) indicates that there is a general average increase, with but few fluctuations, for both crude protein and ash; there is a general increase of carbohydrates and with but one exception, of crude fat. When the results are computed to the dry matter basis, however, it is found that some of the constituents increased so rapidly in the corn that they predominated over the other materials and caused a relative decrease in amount of the others. The fat and carbohydrates are the groups which increase rapidly as the corn ripens and the protein and ash decrease. This was true of the series of samples studied in 1914, though there were a few fluctuations as was to be expected. Table IV contains the summaries of the analyses approached from this point of view.

The location of the 1915 trial at the Central Experiment Station was a series of four adjacent plots in one of the rotation fields. The numbers of the plots upon which the corn was grown were 12, 13, 28 and 29 and their general relation is shown in figure 1. Plot 12 was manured with 10 tons rotted manure per acre in the fall of 1910, five years before, for the 1911 crop. Plot 13 was similarly treated with 5 tons of rotted manure per acre. All four of the plots were seeded to wheat in 1914 but were plowed up in July and fallowed. The preparation of the plots for the corn grown in 1915 was as follows: double disced, April 12th and May 11th; harrowed, May 20th and 24th; planted, May 27th; harrowed, June 3rd; cultivated, July 8th, 9th, 14th, 17th and 23rd and August 5th and 6th.

It was originally intended to harvest large samples at the five stages previously mentioned with smaller samples for analytical purposes about half way between each pair of the others. The early part of the season was so cool however, that the corn was greatly retarded and ripened unevenly. Hence, cuttings were made at numerous intervals of about 5 or 6 days, every second or third lot being harvested on a tenth-acre scale for the yields as well as comparative composition. Notes were kept upon the condition of the samples, especially the range in the maturity of the ears. While the samples do not represent uniformly definite stages, such as dough or glazed, etc., they may be taken as fairly typical of the general maturity of the corn, in so far as it was possible to choose the average run of field specimens. The field and analytical data, as might be expected, show some fluctuations in maturity from one harvesting to another but these are not any greater than is usually met with in

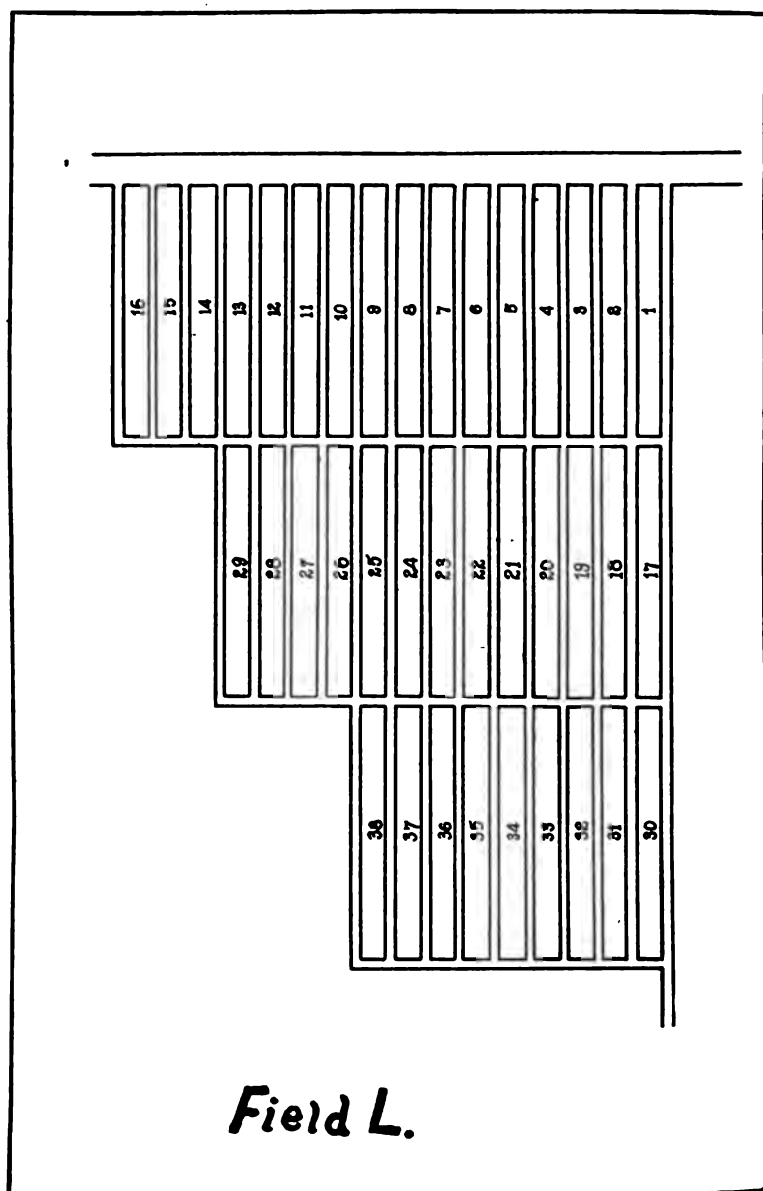


Fig. 3.—Location of 1915 trial, plots 12, 13, 28 and 29.

this kind of work. The yields of dry matter, etc., of the 1915 samples as determined by analysis are given in Table V.

The maximum green weight of the 1915 samples was between the milk and dough stages. The maximum weight of dry matter was between the dough and ripe stages, practically at the glazed stage. The carbohydrates and crude fat also reached their maximum at

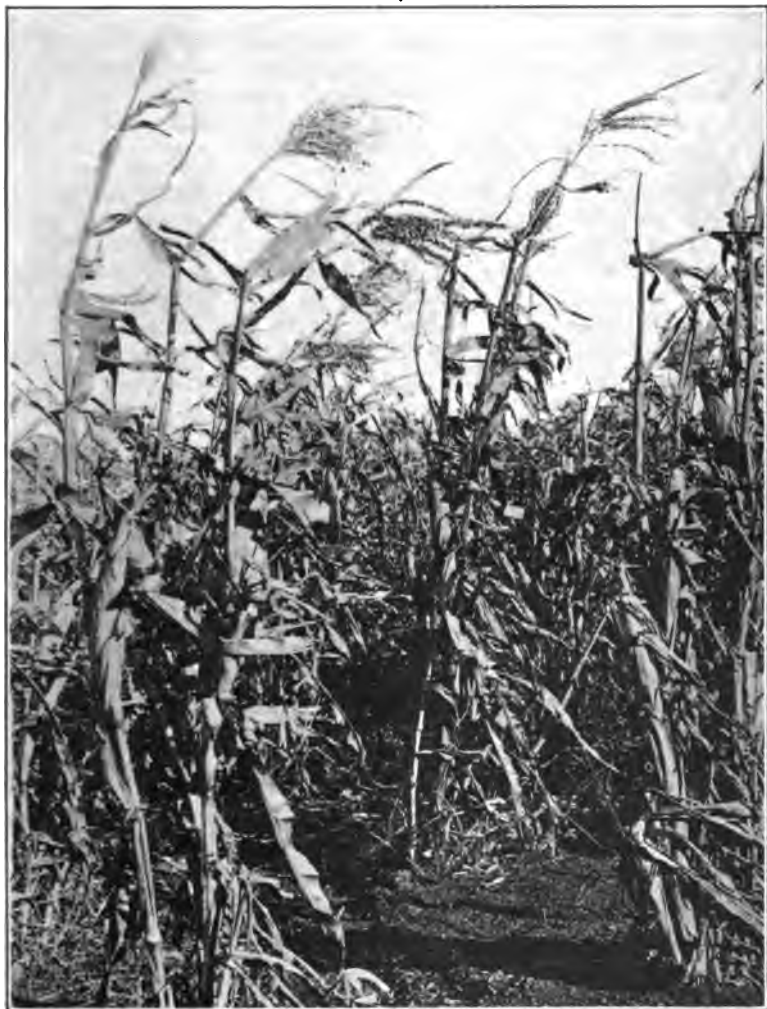


Fig. 4—Corn after last cutting, October 10th.

this stage while the crude protein, fiber and ash were greatest at about the dough stage. These results coincide quite closely with those for 1914. It is desirable, for purposes of comparison with the results for 1914 to choose samples of corn from the 1915 harvest which represents the five stages previously mentioned. Within certain ap-

proximate limits it has been possible to select a number of samples which respond to this need fairly well. This selection results principally by using the samples of the most mature corn to be found at the various stages and carefully considering the notes in regard to the condition of the ears as they were gathered. There is a gradual increase of the different constituents from the tasseled to the ripe stage for both 1914 and 1915. A comparison of the summaries of analyses for these years (Table VI) discloses the fact that, while there is some difference in values, there is an approximately close similarity in the composition of the samples representing the same stages for the two years. The dry matter is about 9% higher for the ripe stage of the 1915 crop than for the 1914 sample and this difference is almost entirely due to carbohydrates.

The data would seem to indicate that (with the single exception of the milk and dough stages for 1915) the 1915 samples were more carefully chosen or represented a greater maturity than the 1914. Of course, it must be recalled that in 1914 four persons made the selections, the samples were from different localities and grown under different conditions. And, moreover, with the corn grown at the Central Experiment Station in 1914 it seemed that there was not much difference in the various samples for a number of reasons. For example, the first sample was not taken early enough, the maturity of the field of corn was uneven and the samples were taken at too short intervals. The summary of the 1914 samples shows one or two slight fluctuations while that for the 1915 crop is normal. Considering all the factors which entered into the growth of the corn for the two years, there is not much difference in the percentage figures except for the larger amount of dry matter and carbohydrates in the ripe stage for 1915.

The difficulty of choosing representative samples can be readily appreciated from the nature of the season and from the fact that a relatively small interval of time was allowed between cuttings. Another factor which undoubtedly had an influence in the maturity of the crop was the large number of suckers and the rank growth which they attained towards the end of the trial. Inasmuch as this growth of suckers probably delayed the maturity of the stalks and formed a rather large portion of the total yield, careful notes were kept upon this condition. Whereas the average number of stalks per hill for all the observations made throughout the trial was 3.087, the average number of suckers per hill was 3.41. This relative abundance of suckers is characteristic of the Mercer flint variety. When weighing the analytical samples of the last four cuttings, the suckers were weighed separately and found to make up from 5.2 to 10.0% (an average of 6.8%) of the total weight of the samples. It is important to note the green weights of the individual rows as they were cut. This information is valuable in giving an idea as to the evenness of the stand. The sum of the six rows cut at each harvest was exactly one-tenth acre. The range in the weights of the rows cut at one time is very great but diminishes from 41% of the maximum at the first harvest to about 10.5% for the fifth harvest. Detailed information in regard to the stand is found in Table VII.

Toward the end of the growing period, when it was feared that an early frost might suddenly terminate the trial, samples of corn that were the most mature to be found in the field at the time were selected for analysis and comparison made with the run of field product. As a result of three such comparisons it was found that there was considerable difference in the composition of these selected samples and that the difference became greater as the trial progressed. In other words, here is a field of corn that because of unfavorable conditions (in this case cold weather) has not matured evenly. Out of this field there is selected at three different times two sets of samples, one, as far as could be judged the average of the field in maturity, and the other the most ripe to be secured. These two sets were analyzed separately and the chemical analysis found to support the field selection, that is the samples chosen as most mature were found to have a higher proportion of dry matter and its individual constituents than the average run of field product. And, again, when these results were computed to a basis of yield in pounds per acre, the superiority of the most mature samples was apparent. Assuming the same yield of green matter in both cases, the amount of nutrient materials as protein, fat and carbohydrates was greater for the riper series. This was true, not only of the plant as a whole but also of the cobs and kernels; it would naturally be expected, of course, that as the plant matured the ears would give evidence of this greater maturity. The detailed data for this comparison is given in Table VIII. The use of the same green weight in both cases might be criticised because it may be said that the green weight decreases as the corn matures. But as a rough measure of comparison they are interesting in suggesting what yields might be secured under favorable circumstances. An illustration of the difference in such a comparison is given in Table IX. In this case the data is based upon analyses of the most mature and the run of field corn cut October 9th. The yields have been computed to a ten acre basis, which would give approximately enough silage to fill one 100 ton silo.

Another interesting result of this trial was apparent early in the season. It was noticed that there was quite a difference in the maturity of the corn grown upon the different plots. When the cropping history was examined, it was learned that two of the four plots used in the trials had been manured in 1910. It may seem that the manuring was so light and so many years preceding the trial as not to have had an effect in this particular case. There was certainly some difference, however, in the corn from the different plots and this seemed to be the only factor which could be judged as responsible. The obvious field differences in the appearance of the corn and the differences showed by the analyses continued through the season and it seemed advisable to tabulate the data for a study of the effect of manuring corn upon its composition and maturity (Table X). With the exception of a few fluctuations it was found that in the majority of harvestings there was a greater maturity of the manured corn than of the unmanured. For example, a comparison of the average of all the harvestings of the manured and

unmanured samples shows that with the average number of stalks per hill practically the same, there was a greater green weight of the manured corn for the stalk, the hill and the acre basis. Moreover, the average percentage of dry matter was considerably greater. There was a greater number of suckers as well as ears per hill upon the manured and the average green weight of the ears, their proportion of dry matter and the dry matter per acre was greater upon the manured. The preceding summary applies to the samples taken for analysis. When the data is considered which was compiled for the tenth-acre yields such differences do not appear in detail but the average percentage of dry matter and the weight of dry matter per acre are slightly larger for the manured than for the unmanured. In other words, the relative proportion of the nutrient materials in the crop was greater in both the whole plant and the ears of the samples grown on manured land than on those where no manure had been applied.

For purposes of reference a summary of all the analyses for 1915 made at the different stages of development appears in Table XI. This contains the same information as given in previous tables but is arranged to show the average of all the results by harvests.

The composition of the corn plant at various stages of growth has been studied by a number of investigators: Babcock and Ladd working independently at the New York (Geneva) Experiment Station¹; Jones and Huston at the Indiana (Purdue) Experiment Station²; Schweitzer at the Missouri Experiment Station³; and Hornberger (Germany)⁴. For the purpose of comparing the results obtained under North Dakota conditions with those of other states where similar trials have been carried on, a number of tables have been inserted in this report which summarize the results of those trials. The object of the New York experiments was to ascertain the best stage for cutting corn for the silo. The King Philip variety was used in the trial. Among other results Ladd concluded that the greatest weight of green fodder was between the period of full silking and the milky stage of the kernel; that the total weight diminishes after this date but that the total dry matter increases; that between the period of glazing and full ripening of corn there was a large increase in amounts of sugar and starch; that for the greatest amount of nutriment considered from a chemical standpoint, corn should not be cut before it had well ripened. A condensed summary of Ladd's results appears in Table XII.

A tabular statement of the Indiana trials is given in Table XIII. The green weight was not given in the report but it is evident that the maximum amount of dry matter is at the ripe stage. The maximum amounts of protein, fat, fibre and starch appear in the sample which had been shocked and was thoroughly cured. The ash and nitrogen-free extracts, however, reached their maximum at the ripe stage.

1 8th Annual Report (1890), N. Y. (Geneva) Agr. Expt. Sta.

2 Bul. 175, Ind. (Purdue) Agr. Expt. Sta.

3 Bul. 9, Mo. Agr. Expt. Sta.

4 A Book on Silage, F. W. Woll.

SUMMARY.

The harvesting of any crop grown for fodder purposes should occur at the time the crop has the greatest food value. In the case of maize, for example, there is a progressive change in the composition of the plant as it matures, the percentage of water decreasing and the percentage of the dry matter constituents increasing. When applied to the basis of yield per acre there is an increase in amount of dry matter. It may be stated, as a general principle, therefore, that the more mature the corn the greater the quantity of protein, fat and carbohydrates.

Corn grown in North Dakota, however, does not give as high yields of these materials as corn grown in New York or Indiana, nor is there such a rapid increase of them from one stage to another. A comparison of the yields of dry matter, protein and carbohydrates of these three states (Table XIV) shows the maximum yields for North Dakota were practically reached at the glazed stage; in fact there was a loss of protein at the ripe stage. On the other hand there was a steady increase of all the constituents in the corn grown in Indiana and New York up to the maximum at the ripe stage. In other words, then, no variety of corn should be grown in this state which will not reach at least the glazed stage of maturity. It is not advisable to grow corn suitable for southern states on the supposition that a greater yield of nutrients is obtained. Such corn will not mature under ordinary circumstances in this state and the dry matter constituents will not increase appreciably as the season advances.

Another reason why varieties of corn should be grown in North Dakota which will reach maturity under the average climatic conditions of the state is that more mature corn makes better silage. Corn cut in the watery stages gives a poorer silage which is apt to be too acid. The composition of the riper corn changes less in the silo and there is less loss of food value of the corn. As a matter of economy also there is less water to be handled in the riper crop and the corn is easier to harvest and to silo. It has been found also that corn cut after the glazing stage is more easily digested than that cut before the glazing stage. In a summary of American digestion experiments* the average percentage of digestibility of corn fodder and of corn silage has been shown to be greater for the more mature corn.

	Corn Fodder	Corn Silage
Cut before glazing stage, 13 experiments	65.7	67.4
Cut after glazing stage, 10 experiments	70.7	73.6

ACKNOWLEDGMENT.

The writer desires to acknowledge the assistance of the following for field treatments and notes: Supt. O. A. Thompson of the Edgeley Sub-station; Supt. L. R. Waldron of the Dickinson Sub-station; Supt. C. H. Ruzicka of the Williston Sub-station; Messrs. O. W. Dynes and R. C. Doneghue of the Central Experiment Station.

* The Feeding of Animals, page 212, by W. H. Jordan.

TABLE I. CLIMATIC DATA
(Observations made at the Central Experiment Station)

Total annual rainfall (inches)							
20-yr. av. ¹ 20.25; 1914—16.32; 1915—16.93.							
Monthly rainfall (inches)							
20-yr. av. ²	May 2.73	June 3.32	July 3.10	Aug. 2.98	Sept. 2.27	October 1.73	Total 16.23
1914—	0.81	6.28	3.10	2.11	0.80	1.01	14.11
1915—	3.07	6.74	1.92	0.94	1.10	0.70	14.47
Mean daily temperature (by months)							
20-yr. av. ³	May 54.0 ⁴	June 63.9	July 67.8	Aug. 68.3	Sept. 57.6	October 44.5 ⁴	Average 59.0
1914—	57.5	64.5	74.0	65.5	61.5	53.5	62.7
1915—	51.5	59.0	65.2	65.2	58.7	48.3	57.9
Total hours of sunshine.							
13-yr. av. ⁵	May 227.3	June 243.9	July 285.7	Aug. 234.9 ⁶	Sept. 192.2	October 148.4 ⁷	Total 1332.4
1914—	238.5	195.0	299.6	171.5	140.8	206.0	1252.0
1915—	242.9	262.7	299.8	300.6	170.6	148.8	1425.4
Average daily hours of sunshine.							
13-yr. av. ⁵	May 7.33	June 8.13	July 9.21	Aug. 7.48	Sept. 6.40	October 4.79	Average 7.24
1914—	7.70	6.52	9.66	5.53	4.69	6.64	6.81
1915—	7.84	8.76	9.66	9.70	5.68	4.80	7.73

¹ 1893-1913 (1910) omitted, record incomplete).

² 1894-1913 inclusive.

³ Average for 19 years.

⁴ Average for 17 years.

⁵ 1899-1913 (omitting 1910 & 1911)

⁶ Average for 11 years.

⁷ Average for 12 years.

TABLE II. DESCRIPTION OF 1914 SAMPLES
(Weights in pounds per acre)

Stage of growth	Date cut	Green weight	Water	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Grown at Edgeley—Variety Minnesota No. 23.									
Tasseled.....	July 27	5790	4980	810 (14.00%) ¹	111.2	15.1	212.3	74.2	400.0
Milk.....	Aug. 11	8390	6973	1417 (16.76%)	162.8	24.2	335.0	115.0	769.0
Dough.....	Aug. 27	9400	7520	1880 (20.00%)	187.3	30.9	493.0	145.5	1024.0
Glazed.....	Sept. 3	7490	5500	1990 (26.64%)	186.0	46.1	382.3	126.8	1258.0
Ripe.....	Sept. 15	5575	3841	1734 (31.10%)	154.6	40.8	362.5	95.8	1080.0
Grown at Williston—Variety Northwestern Dent.									
Tasseled.....	Aug. 1	6715	5723	992 (14.76%)	143.2	13.1	261.6	96.0	478.0
Milk.....	Aug. 20	11650	9745	1905 (16.30%)	208.5	19.4	464.0	163.0	1047.0
Dough.....	Sept. 7	13530	11155	2375 (17.54%)	241.0	33.6	669.0	170.5	1263.0
Glazed.....	Sept. 17	10720	8080	2640 (24.60%)	251.0	54.6	648.0	158.8	1525.0
Ripe.....	Oct. 16	7300	4310	2900 (40.90%)	257.5	43.7	865.0	216.5	1600.0
Grown at Experiment Station—Variety Mercer flint.									
Tasseled ²	Aug. 8	19450	16080	2970 (15.60%)	306.0	39.2	698.0	223.5	1705.0
Milk.....	Aug. 17	23500	19385	4115 (17.66%)	441.0	50.3	933.0	326.0	2398.0
Dough.....	Aug. 26	22580	17990	4590 (20.32%)	395.0	85.5	1010.0	271.0	2826.0
Glazed.....	Sept. 3	24020	17760	6260 (26.05%)	520.0	109.0	1238.0	324.3	4070.0
Ripe.....	Sept. 10	21620	15620	6000 (27.85%)	517.0	149.5	1135.0	315.0	3890.0

TABLE II. DESCRIPTION OF 1914 SAMPLES—Continued
(Average of all trials)³

Stage of growth	Green weight	Water	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Tasseled	10518	8928	1591 (14.79%)	186.8	22.5	390.6 ¹	131.2	861.0
Milk	14513	12034	2479 (16.99%)	270.8	31.3	577.3	201.3	1404.7
Dough	15170	12222	2938 (19.29%)	274.4	50.0	724.0	195.7	1704.3
Glazed	14077	10447	3630 (25.76%)	319.0	69.9	756.1	203.3	2284.3
Ripe	11498	7924	3175 (33.28%)	309.7	78.0	787.5	209.1	2190.0

¹ Percentage of dry matter in green crop.

² Somewhat past tasseled stage.

³ Omitting Dickinson samples.

TABLE III. SUMMARY OF THE ANALYSES OF 1914 SAMPLES
Whole plant—Original basis—Figures in percentage

	Crude protein					Carbohydrates				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Dickinson	2.12	2.14	2.76	2.41	3.46	5.23	10.90	13.72	15.26	20.00
Edgeley	1.94	1.94	1.99	2.48	2.77	6.90	9.16	10.88	16.76	19.36
Williston	2.13	1.79	1.78	2.34	3.53	7.11	8.97	9.33	14.22	21.92
Ex. Station	1.61	1.86	1.75	2.17	2.39	8.94	10.20	12.52	16.92	17.99
Average	1.95	1.93	2.07	2.35	3.04	7.04	9.81	11.61	15.79	19.82
	Ether extract					Ash				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Dickinson	0.17	0.22	0.47	0.50	1.05	1.20	1.66	1.83	1.63	1.96
Edgeley	0.26	0.29	0.33	0.62	0.73	1.28	1.37	1.55	1.69	1.72
Williston	0.19	0.17	0.25	0.51	0.60	1.43	1.40	1.26	1.48	2.97
Ex. Station	0.21	0.21	0.38	0.45	0.69	1.18	1.39	1.20	1.35	1.44
Average	0.21	0.22	0.36	0.52	0.77	1.27	1.45	1.46	1.54	2.02

TABLE IV. SUMMARY OF THE ANALYSES OF 1914 SAMPLES
Dry matter basis—Figures in percentage

Crude protein										
	Whole plant					Cobs and kernels				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Dickinson	17.42	11.81	12.06	9.83	10.76	x	x	10.81	10.39	10.85
Edgeley	13.73	11.58	9.96	9.29	8.92	x	13.00	9.81	10.02	10.30
Williston	14.42	10.99	10.20	9.54	8.64	x	x	11.58	10.74	10.42
Ex. Station	10.28	10.62	8.62	8.32	8.60	x	x	10.35	9.20	8.87
Average	13.96	11.25	10.21	9.24	9.23	x	x	10.64	10.09	10.11
Crude fat										
	Whole plant					Cobs and kernels				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Dickinson	1.41	1.20	2.06	2.05	3.27	x	x	1.54	2.80	4.20
Edgeley	1.87	1.73	1.64	2.31	2.36	x	2.86	1.95	3.44	3.16
Williston	1.32	1.02	1.41	2.07	1.46	x	x	2.74	2.95	3.25
Ex. Station	1.34	1.21	1.87	1.74	2.49	x	x	2.13	2.36	2.91
Average	1.48	1.29	1.74	2.04	2.39	x	x	2.09	2.89	3.38
Carbohydrates										
	Whole plant					Cobs and kernels				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Dickinson	47.05	60.25	59.96	62.35	62.21	x	x	73.70	75.02	74.50
Edgeley	49.25	54.65	54.50	62.80	62.30	x	70.20	75.70	76.10	75.90
Williston	48.20	55.00	53.20	57.85	53.75	x	x	71.25	72.65	73.10
Ex. Station	57.30	57.81	61.60	65.00	64.80	x	x	69.62	73.05	76.60
Average	50.45	56.93	57.31	62.00	60.76	x	x	72.57	74.20	75.02
Ash										
	Whole plant					Cobs and kernels				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Dickinson	9.90	9.15	8.01	6.83	6.09	x	x	1.97	1.93	1.90
Edgeley	9.15	8.17	7.74	6.35	5.54	x	2.64	2.18	1.82	1.95
Williston	9.71	8.58	7.22	6.02	7.25	x	x	2.10	2.25	2.23
Ex. Station	7.55	7.86	5.92	5.18	5.20	x	x	1.97	1.93	1.95
Average	9.58	8.44	7.22	6.09	6.02	x	x	2.05	1.98	2.01

x = not determined.

TABLE V. DESCRIPTION OF 1915 SAMPLES
Weights in pounds per acre—Yields based upon one-tenth acre cuttings.

Date cut	Maturity of ears	Green weight	Water	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Aug. 19...	Ears not formed ¹	13515	11645	1870	223.3	23.6	476.5	161.0	986.0
Aug. 30...	Ears not very large, many just forming ²	19896	17211	(13.82%) (32.29%) 2685	298.0	26.9	685.0	263.5	1479.0
Sept. 13...	Many in milk stage but still many with no kernels ³	26047	21487	(13.48%) 4560	434.0	56.9	1070.0	273.5	2728.0
Sept. 29...	Principally dough stage ⁴	25551	19951	(17.50%) 5600	518.0	102.0	1207.0	302.0	3472.0
Oct. 9.....	From dough to ripe ⁵	17727	11097	(21.92%) 5730	493.0	127.0	1168.0	279.0	3678.0

Intermediate samples--Yields from hill basis									
Aug. 25...	Ears not formed	18450	15880	2570	345.0	30.5	634.0	195.8	1408.0
Sept. 4....	Ears not very large, many just forming	23750	20000	(13.93%) 3750	391.7	51.9	935.8	250.0	2117.8
Sept. 8....	Just entering upon the milk stage	29100	24080	(15.80%) 5010	509.2	72.3	1242.5	323.6	2867.0
Sept. 18...	Mostly in different periods of milk stage	30600	24800	(17.23%) 5800	541.0	60.2	1333.8	334.4	3525.0
Sept. 24...	Late milk and soft dough stages	28933	22913	(18.95%) 6020	576.0	109.8	1341.0	312.0	3695.0
Oct. 4.....	From late milk to glazed	25650	20110	(20.79%) 5540	511.3	93.5	1212.4	320.7	3432.8

¹ As near as could be judged in the tasseled stage.

² As near as could be judged in the milk stage.

³ As near as could be judged in the dough stage.

⁴ As near as could be judged in the glazed stage.

⁵ As near as could be judged in the ripe stage.

TABLE VI. COMPARISON OF THE ANALYSES OF THE 1914 AND 1915 SAMPLES
Whole plant—Original basis—Figures in percentage

	1914 ¹					1915				
	Tassel	Milk	Dough	Glazed	Ripe	Tassel	Milk	Dough	Glazed	Ripe
Water	85.22	83.10	79.89	74.70	66.71	84.20	80.87	79.40	72.40	57.35
Dry matter	14.78	16.90	20.11	25.30	33.29	15.80	19.13	20.60	27.60	42.65
Crude protein	1.95	1.93	2.07	2.35	3.04	1.64	1.74	2.04	2.78	3.40
Crude fat	0.21	0.22	0.36	0.52	0.77	0.21	0.26	0.36	0.66	0.98
Crude fiber	3.54	4.03	4.69	5.23	7.35	3.97	4.53	4.55	5.44	7.89
Ash	1.27	1.45	1.46	1.54	2.02	1.05	1.10	1.15	1.27	1.79
Carbohydrates	7.04	9.81	11.61	15.79	19.82	8.91	11.53	12.52	17.46	28.58

¹ Average of analyses of three varieties grown at four stations.

TABLE VII. NOTES WITH REGARD TO THE STAND OF CORN, 1915

6 rows—342 hills— $\frac{1}{10}$ acre (Weights in pounds)

	Percent of perfect stand	Av. No. stalks per hill	Av. No. suckers per hill	Av. wt. per hill	Av. wt. per stalk	Range in wt. of rows			Difference between minimum and maximum
						Minimum	Maximum	Mean	
Aug. 19	96.5 ¹	3.00	2.79	3.95	1.32	162.4	276.4	225.25	114.0
Aug. 30	89.5	2.94	3.19	5.82	1.98	263.5	372.0	331.6	108.5
Sept. 13	96.5	3.37	3.57	7.63	2.26	390.7	458.9	434.1	68.2
Sept. 29	92.7	3.16	3.90	7.48	2.36	385.7	451.5	425.8	65.8
Oct. 9	92.7	2.96	3.60	5.18	1.74	277.4	310.0	295.5	32.6
Average	93.6	3.087 ²	3.41						

¹ These figures represent the stand of each row as cut. The data is presented to give an idea of the actual field conditions. Missing and abnormal hills were, however, replaced by adjacent hills in order to secure the yield of a perfect stand.

² The average number of stalks per hill for all of the harvestings by rows was 3.087. Multiplying this figure by 3420, the number of hills per acre, gives a stand of 10,560 stalks per acre.

TABLE VIII. COMPARISON OF THE MOST MATURE CORN WITH THE AVERAGE FOR 1915
Percentage Composition

	Whole plant							Cobs and kernels						
	Moisture	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract	Moisture	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Sept. 8—Av. run of field	83.11	16.89	1.78	0.24	4.17	1.13	9.57	84.95	15.05	2.34	0.19	2.34	0.61	9.06
Most mature	82.08	17.92	1.63	0.26	4.49	1.02	10.52	78.96	21.04	2.44	0.26	4.55	0.66	13.13
Sept. 29—Average ..	79.17	20.83	1.99	0.34	4.66	1.15	13.03	68.20	31.79	3.45	0.91	4.47	0.79	22.17
Most mature	74.80	25.20	2.76	0.60	4.79	1.15	15.90	61.13	38.87	3.74	1.50	4.68	0.91	28.04
Oct. 9—Average	72.89	27.11	2.43	0.52	5.75	1.40	17.01	63.19	36.81	3.97	1.29	4.47	0.79	26.31
Most mature	57.35	42.65	3.40	0.98	7.89	1.79	28.58	50.25	49.75	4.52	1.63	5.02	0.92	37.69
Yield per acre—pounds*														
Sept. 8—Average	24180	4920	517.0	70.1	1210.0	328.5	2785.0	4145	735	114.4	9.3	138.9	29.8	443.0
Most mature	23890	5210	474.0	75.8	1308.0	296.5	3080.0	3850	1030	119.3	12.7	222.5	32.2	642.0
Sept. 29—Average ..	21450	5650	539.0	92.1	1262.0	312.0	3534.0	4350	2030	220.5	58.1	285.4	50.4	1413.0
Most mature	20270	6330	748.0	162.6	1300.0	312.0	4310.0	3895	2485	239.0	95.7	298.0	58.1	1790.0
Oct. 9—Average	18520	6130	550.0	117.8	1302.0	317.0	3850.0	3837	2233	241.0	78.4	271.0	47.9	1595.0
Most mature	12990	9660	770.0	222.0	1787.0	406.0	6470.0	3050	3020	274.0	99.0	304.0	55.8	2284.0

* Data based upon small samples taken for analysis.

TABLE IX. YIELD FROM TEN ACRES OF CORN
Grown for silage

	Late maturing lbs.	Early maturing lbs.
Water	129,170	101,670
Dry matter	48,100	75,600
Crude protein	4,310	8,025
Crude fat	922	1,738
Crude fiber	10,200	14,000
Ash	2,482	3,175
Carbohydrates	30,140	50,850

Note:—These figures are based upon analyses of "mature" and "run of field" corn cut October 9th.

TABLE X. COMPARISON OF CORN GROWN UPON MANURED AND UNMANURED LAND
(Average of all the samples analyzed)

	Manured			Unmanured		
	Small samples		Tenth acre yields	Small samples		Tenth acre yields
	Whole plant	Cobs and kernels	Whole plant	Whole plant	Cobs and kernels	Whole plant
Average number of stalks per hill	3.43	.....	3.06	3.44	.....	3.10
Average number of suckers per hill	5.06	.....	3.50	4.09	.....	3.26
Average green weight per hill (lbs.)	7.43	1.857	5.95	7.00	1.514	6.00
Average green weight per acre (lbs.)	25410	6500	20340	23450	.....	20530
Average percentage dry matter in sample	19.46	24.78	19.95	18.16	21.74	19.61
Average weight dry matter per acre (lbs)	5015	1611	4088	4280	1145	4034
Average percentage crude protein	1.895	2.812	.....	1.825	2.527	.....
Average percentage crude fat	0.306	0.630	.....	0.268	0.513	.....
Average percentage crude fibre	4.422	3.506	.....	4.153	3.229	.....
Average percentage ash	1.162	0.997	.....	1.116	0.635	.....
Average percentage carbohydrates	11.668	16.809	.....	10.852	14.556	.....

TABLE XI. SUMMARY OF THE ANALYSES AT DIFFERENT STAGES OF DEVELOPMENT
Date of harvest, August 19th—Number of plants, 85.

Whole plant				Stalks, blades, etc.			Kernels and cob (ear)		
	Average per cent	Per cent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average per cent	Per cent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Per cent of D. M.
Moisture	86.18		2045	1870					
Dry matter	13.82		39.0	36.7					
Nitrogen	0.26	1.91	244.0	223.3					
Crude protein	1.63	11.92	25.8	23.6					
Crude fat	0.17	1.26	521.5	476.5					
Crude fibre	3.52	25.47	175.6	161.0					
Ash	1.18	8.58	1080.6	988.0					
Nitrogen-free extract	7.31	52.77							

Notes: (a) Badis small samples. (b) Badis 1/10 acre samples.

(A) Date August 25th—Number of plants 18.

Whole plant				Stalks			Kernels and cob		
	Average per cent	Per cent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average per cent	Per cent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Per cent of D. M.
Moisture	86.07		2570						
Dry matter	13.93		48.9						
Nitrogen	0.26	1.80	345.0						
Crude protein	1.64	11.84	30.5						
Crude fat	0.16	1.17	740.7						
Crude fibre	3.44	25.32	195.8						
Ash	1.06	7.62	1408.0						
Nitrogen-free extract	7.66	54.73							

*(2nd) Date August 30th—Number of plants 54.

Whole plant				Stalks			Kernels and cob		
	Average per cent	Per cent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average per cent	Per cent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Per cent of D. M.
Moisture	86.52		2895	2985					
Dry matter	13.48		51.6	47.6					
Nitrogen	0.24	1.77	322.4	298.0					
Crude protein	1.49	11.09	29.4	26.9					
Crude fat	0.13	1.00	634.0	593.5					
Crude fibre	3.44	24.64	213.2	203.5					
Ash	0.99	7.58	1590.0	1479.0					
Nitrogen-free extract	7.42	55.04							

TABLE XI. SUMMARY OF ANALYSES AT THE DIFFERENT STAGES OF DEVELOPMENT—Continued
(B) Date of harvest. September 4th—Number of plants 18

	Whole plant				Stalks				Kernels and cob			
	Average percent	Percent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average percent	Percent of D. M.	Pounds per acre	Average percent	Percent of D. M.	Pounds per acre	Percent of D. M.	Pounds per acre
Molature.....	84.20				83.53			88.78				
Dry matter.....	15.80		3750		16.47		3412	11.22				338
Nitrogen.....	0.26	1.67	62.7		0.26	1.59	54.3	0.28	2.49	8.4		8.4
Crude protein.....	1.64	10.43	391.7		1.63	9.94	339.2	1.73	15.54	52.5		52.5
Crude fat.....	0.21	1.36	51.9		0.22	1.38	47.1	0.16	1.42	4.8		4.8
Crude fibre.....	3.97	25.12	935.8		4.28	25.74	878.0	1.92	17.12	57.8		57.8
Ash.....	1.05	6.64	250.0		1.18	6.88	235.0	0.50	4.45	15.0		15.0
Nitrogen-free extract.....	8.91	56.44	2117.8		9.23	56.05	1910.0	6.90	61.46	207.8		207.8
(C) Date September 8th—Number of plants 33												
	Whole plant				Stalks				Kernels and cob			
	Average percent	Percent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average percent	Percent of D. M.	Pounds per acre	Average percent	Percent of D. M.	Pounds per acre	Percent of D. M.	Pounds per acre
Molature.....	82.77				82.79			82.95				
Dry matter.....	17.23		5010		17.21		4177	17.05				833
Nitrogen.....	0.28	1.61	81.7		0.26	1.49	62.6	0.38	2.29	19.1		19.1
Crude protein.....	1.73	10.09	509.2		1.60	9.33	390.0	2.38	14.33	119.2		119.2
Crude fat.....	0.25	1.44	72.3		0.26	1.49	62.6	0.21	1.17	9.7		9.7
Crude fibre.....	4.28	24.83	1242.5		4.44	25.80	1078.0	3.41	19.74	164.5		164.5
Ash.....	1.09	6.36	323.6		1.19	6.89	292.0	0.63	3.79	31.6		31.6
Nitrogen-free extract.....	9.88	57.28	2867.0		9.72	56.48	2360.0	10.42	60.97	507.0		507.0
(3rd) Date September 13th—Number of plants 65												
	Whole plant				Stalks				Kernels and cob			
	Average percent	Percent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average percent	Percent of D. M.	Pounds per acre	Average percent	Percent of D. M.	Pounds per acre	Percent of D. M.	Pounds per acre
Molature.....	82.50				82.69			81.66				
Dry matter.....	17.50		4700		17.31		3728	18.34				972
Nitrogen.....	0.27	1.53	71.6		0.24	1.41	52.6	0.37	1.96	19.0		19.0
Crude protein.....	1.97	9.53	448.2		1.52	8.80	328.3	2.29	12.33	119.9		119.9
Crude fat.....	0.22	1.25	59.4		0.25	1.24	46.3	0.25	1.35	13.1		13.1
Crude fibre.....	4.11	23.44	1096.8		4.28	24.73	922.0	3.29	17.98	174.8		174.8
Ash.....	1.05	6.00	286.8		1.17	6.77	252.5	0.64	3.53	34.3		34.3
Nitrogen-free extract.....	10.12	59.78	2836.0		10.12	59.24	2210.0	11.86	64.44	626.0		626.0
(D) Date of harvest, September 18th—Number of plants 21												
	Whole plant				Stalks				Kernels and cob			
	Average percent	Percent of D. M.	Pounds per acre (a)	Pounds per acre (b)	Average percent	Percent of D. M.	Pounds per acre	Average percent	Percent of D. M.	Pounds per acre	Percent of D. M.	Pounds per acre
Molature.....	81.05				81.32			80.31				
Dry matter.....	18.95		5800		18.68		4580	19.69				1220
Nitrogen.....	0.28	1.49	86.5		0.26	1.40	64.2	0.36	1.83	22.3		22.3
Crude protein.....	1.76	9.31	541.0		1.63	8.76	401.5	2.24	11.45	139.5		139.5
Crude fat.....	0.20	1.03	60.2		0.17	0.90	41.2	0.82	1.56	19.0		19.0
Crude fibre.....	4.32	22.87	1333.8		4.58	24.48	1122.0	3.32	17.36	211.8		211.8
Ash.....	1.09	5.76	334.4		1.21	6.47	206.0	0.62	3.15	38.4		38.4
Nitrogen-free extract.....	11.59	61.03	3525.0		11.06	59.24	2715.0	13.19	66.46	810.5		810.5

(E) Date September 24th—Number of plants 32

Whole plant			Stalks		Kernels and cob	
Moisture.....	78.21		81.45	3825	74.33	2195
Dry matter.....	20.79		18.55	82.4	25.67	32.6
Nitrogen.....	0.32		0.25	1.37	0.56	1.50
Crude protein.....	1.99		1.58	8.58	2.89	11.26
Crude fat.....	0.98		0.26	1.39	0.67	2.58
Crude fibre.....	4.53		4.73	25.48	4.24	16.66
Ash.....	1.08		1.20	6.52	0.71	2.87
Nitrogen-free extract.....	12.82		10.77	58.37	17.16	68.61
				2280.0		1485.0

(4th) Date September 29th—Number of plants 57

Whole plant			Stalks		Kernels and cob	
Moisture.....	78.08		82.31	3800	66.43	2140
Dry matter.....	21.92		17.69	50.6	33.57	36.2
Nitrogen.....	0.35		0.23	1.33	0.56	1.89
Crude protein.....	2.18		1.47	8.35	3.52	10.55
Crude fat.....	0.40		0.16	0.92	1.06	3.13
Crude fibre.....	4.99		4.76	26.89	4.52	13.84
Ash.....	1.15		1.29	7.34	0.82	2.46
Nitrogen-free extract.....	13.97		10.00	56.50	23.39	70.26
				2146.0		1503.0

(F) Date of harvest, October 4th—Number of plants 20

Whole plant			Stalks		Kernels and cob	
Moisture.....	78.45		81.98	3540	67.14	2000
Dry matter.....	21.55		18.02	49.6	32.86	32.2
Nitrogen.....	0.32		0.25	1.40	0.53	1.81
Crude protein.....	1.98		1.57	8.74	3.31	10.09
Crude fat.....	0.98		0.17	0.94	0.99	3.01
Crude fibre.....	4.57		4.68	25.84	4.30	13.12
Ash.....	1.29		1.42	7.89	0.78	2.37
Nitrogen-free extract.....	13.33		10.12	56.58	23.48	71.39
				2005.0		1427.8

(5th) Date October 9th—Number of plants 80

Whole plant			Stalks		Kernels and cob	
Moisture.....	67.71		73.77	4830	58.88	2490
Dry matter.....	32.29		26.23	56.6	41.12	46.6
Nitrogen.....	0.44		0.30	1.17	0.66	1.63
Crude protein.....	2.75		1.92	7.33	4.15	10.23
Crude fat.....	0.67		0.25	0.97	1.39	3.39
Crude fibre.....	6.46		7.47	28.22	4.65	11.48
Ash.....	1.53		1.91	7.26	0.84	2.06
Nitrogen-free extract.....	20.52		14.67	56.20	30.08	72.83
				2720.0		1810.0

TABLE XII. RESULTS SECURED IN NEW YORK¹
(Weights in pounds per acre)

Stage of growth	Date cut	Green weight	Water	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Tasseled.....	July 30	18040	16420	1619 (8.98%) ²	239.8	72.2	514.2	138.9	653.9
Silk.....	Aug. 9	25740	22660	3078 (11.96%)	436.8	169.8	872.9	201.3	1399.3
Milk.....	Aug. 21	32800	27940	4643 (14.47%)	478.7	228.9	1261.9	232.2	2441.3
Glazed.....	Sept. 7	32280	25020	7202 (22.60%)	643.9	260.0	1755.9	302.5	4239.8
Ripe.....	Sept. 23	28460	20540	7918 (27.81%)	677.8	314.3	1734.0	384.2	4827.6

¹ Analyses by E. F. Ladd, Eighth Annual Report New York (Geneva) Experiment Station 1890.

² Percentage dry matter in green weight.

TABLE XIII. RESULTS SECURED IN INDIANA¹
(Weights in pounds per acre)

Stage	Date of sampling	Dry matter	Crude protein	Crude fat	Crude fibre	Ash	N-free extract	Starch
	June 16.....	6.91	1.749	0.252	1.042	0.838	3.031	
	July 24.....	730.6	149.3	39.7	169.6	89.5	282.5	14.1
Tasseled.....	Aug. 6.....	2244.7	360.3	42.2	670.4	194.7	977.1	62.3
	Aug. 28.....	4567.3	436.0	49.7	1203.1	271.7	2606.8	335.3
Milk.....	Sept. 10.....	6173.1	544.0	94.8	1360.7	328.2	3845.3	
Dough.....	Sept. 24.....	8104.5	565.6	202.4	1522.5	389.0	5425.0	2059.0
Glazed.....	Oct. 1.....	8929.1	659.8	215.4	1602.0	368.4	6083.5	3185.1
Ripe.....	Oct. 8.....	9412.0	691.2	265.5	1737.5	382.5	6335.3	3215.9
	Nov. 12.....	9254.8	729.2	271.4	1821.9	353.4	6078.9	3291.8
Shocked & cured.....	Nov. 12 (left in field)	7259.3	540.0	221.1	1278.9	219.4	4999.9	2507.6

¹ Analyses by Huston & Jones, Purdue Indiana Bul. 175.

TABLE XIV. COMPARISON OF YIELDS OF CORN CONSTITUENTS

Stage of growth	Indiana				New York				North Dakota Average of 1914 - 1915			
	Dry matter	Crude protein	Carbohy- drates	Dry matter	Crude protein	Carbohy- drates	Dry matter	Crude protein	Dry matter	Crude protein	Carbohy- drates	Crude protein
Tasseled	2244	380.3	977.1	1619	239.8	653.9	1730	205.0	923.5	205.0	923.5	205.0
Milk	6173	544.0	3845.3	3078	436.8	1399.3	2582	284.4	1441.8	284.4	1441.8	284.4
Dough	8104	565.6	5425.0	4643	478.7	2441.3	3749	384.2	2266.1	384.2	2266.1	384.2
Glazed	8929	659.8	6083.5	7202	643.9	4239.8	4615	418.5	2878.1	418.5	2878.1	418.5
Ripe	9412	691.2	6335.3	7918	677.8	4827.6	4652	401.3	2934.0	401.3	2934.0	401.3

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North Dakota Agricultural Experiment Station

1 Soya Bean Oil 2 Flax Studies

By W. F. Washburn

Bulletin No. 118

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* Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

SOYA BEAN OIL

By W. F. Washburn

Due to the increasing demand for linseed oil and the scarcity of this article, paint and varnish manufacturers are being forced to seek a substitute for this important material. Of the many oils thus far tested for this purpose the oil from the Soya Bean has been found to be the most satisfactory and adaptable.

Soya Beans, (*Glycine Hispide*) sometimes called Soja Bean, is an erect, leguminous plant, somewhat resembling the native field bean. It is a native of Southeastern Asia, being extensively cultivated and forms, in many sections of the Orient, a very important article of food. According to Morse of the Bureau of Plant Industry, U. S. Department of Agriculture—"More than three hundred distinct varieties of soya beans are known and have been grown by the Department of Agriculture on its testing grounds. The varieties are largely distinguished by color and size of seed, though they differ in maturity, habit, etc."

In certain sections of the United States, chiefly in the South, the soya bean is now being extensively cultivated as a forage and ensilage crop. But, up to the present time, it has not been grown to any extent for the seed. On this account the oil now used in this country is imported or exprest from imported beans.

The United States Commerce Reports for 1915 state that there were imported into this country during 1915,—21,335,213 pounds of soya bean oil, representing a value of \$931,791. From this I would conclude that the oil is being received with favor by the American Manufacturer.

In order to secure a domestic supply of soya bean oil, and at the same time a more dependable product than is now being received from abroad, the Paint Manufacturers Association has, for the past four years, been engaged in an active campaign to interest the American farmer in the cultivation of the soya bean. With this end in view, the Association through the co-operation of State Experiment Stations has cultivated many varieties in an attempt to determine those best suited to the various localities and to produce an oil suitable for paint purposes.

At the request of the Paint Manufacturers Association this department has determined the moisture and oil content of many samples of soya beans and in addition has determined some of the constants of the oils exprest from the different samples. These samples, representing some forty-five varieties, were grown in a number of states under various climatic conditions and include the crops of 1912, 1913, and 1914.

The beans were prepared for analysis by being ground in a mill until fine enough for 95% of the meal to pass thru a 1-mm. sieve. Only a few lumps remaining on a 2-mm. sieve. The samples for analysis were kept in stoppered bottles.

Determination of the moisture was made on 2 gram samples in a vacuum oven at 100° C. maintained for 5 hours with a vacuum of about 25 inches of mercury.

The crude ether extract was determined by the direct method, Bulletin 107 (Revised), Bureau of Chemistry, U. S. Department of Agriculture.

The ground beans were placed in cheese cloth bags and heated to 75-80° C. and the oil exprest by means of hydraulic pressure. The oil from a few samples, which were too small to be worked advantageously in the press, was extracted by means of carbon tetrachloride.

The oil constants were determined according to the methods given in Bureau of Chemistry, U. S. Dept. of Agriculture, Bulletin 107 (Revised.)

The results thus far obtained are of a preliminary nature and are given at this time merely for guidance in further experimental work. However this work clearly indicates that soya beans grown in this country have practically the same oil content as the beans grown abroad and the oil has approrimately the same physical and chemical constants as that exprest from foreign seed.

A general review of the tabulated results would indicate that definite conclusions cannot be safely drawn as to the effect of climatic conditions on the content and the quality of the oil of the different varieties of soya beans, until the beans have been grown at least three years in the same locality.

Many practical exposure tests are now in progress at this Institution to determine the value of Soya Bean oil as a paint vehicle. In this work Soya Bean oil has been used with several pigment combinations both alone and in combination with other paint oils. A report on this part of the work will be presented as soon as sufficient data have been obtained.

TABLE I. SOYA BEANS

Series No. 200—(Black Beauty or Ebony)									
Lab. No.	Reference No.	Grown in	From Seed	Crude Ether Extract	Color of Oil	Constance of the Oil			
						Iodine No. Hanus	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
1794	203	N. J.	202	22.37	Straw	128.0	192.9	1.4730	.9259
1798	205	N. J.		22.64		127.5	193.1	1.4730	.9249
1837	204	N. J.		21.09	Straw	132.35	193.9	1.4738	.9271
1938	210	Ky.		12.81	V. Dark	117.9	190.6	1.4715	.9238
1960	206	Ill.		15.83	Straw	126.4	194.2	1.4730	.926
1968	208	Ala.			Straw	128.9	192.0	1.4732	.927
1969	207	Ind.		18.05	Amber				
1971	209	Ala.		21.21	Straw	124.5	194.2	1.4720	.9235
Average of 7 samples				19.14		126.51	192.99	1.4727	.9255

Lab. No.	Reference No.	Grown in	From Seed	Crude Ether Extract	Color of Oil	Constancy of the Oil			
						Iodine No. Hanus	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
Series No. 300—Ito San									
1526	305	*B. P. I.		20.45		135.16	196.92	1.4735	.9250
1806	306	N. J.		22.03	Pale	128.5	194.6	1.4729	.923
1809	307	N. J.	302	21.62	Straw	130.3	191.2	1.4730	.9242
1814	308	N. J.	304	22.1	Pale	127.3	195.0	1.4735	.9270
1816	311	N. J.	301	22.32	Pale	130.9	192.6	1.4731	.9257
1848	313	R. I.		20.56		134.3	193.2	1.4735	.9260
1851	312	R. I.	301	18.33	Straw	137.8	192.2	1.4739	.9260
1869	315	Penn.	302	20.45	Straw	125.1	191.8	1.4728	.9265
1880	314	Penn.		20.21	Pale	128.4	194.6	1.4730	.928
1883	317	Me.	302	16.46	Straw	140.8	194.3	1.4749	.9256
1886	316	Utah	301	17.77	Pale				
1891	318	N. C.	302	18.24	Straw	127.0	192.0	1.4733	.925
1894	319	N. J.		19.53	Straw	132.4	193.8	1.4731	.9245
1896	320	N. J.	302	18.07	Straw	130.0	195.3	1.4720	.925
1966	321	Ind.		18.34					
2052	325	So. Dak.*	307	16.54		132.7	193.0	1.4732	.9245
2058	326	Wis.*	Ped. 2	16.62		132.5	193.0	1.4732	.925
2071	327	Mont.*	306	19.95	Straw	134.0	191.8	1.4732	.9246
2126	328	Ky.*	304	18.83		125.0	192.9	1.4726	.925
Average of 19 samples				19.39		131.19	193.42	1.4732	.9252

* B. P. I. Bureau of Plant Industry.

Series No. 400—(Mammoth)									
1595	404	W. Va.		20.46		126.08	195.11	1.4728	.9218
1525	403	B. P. I.	31876	18.97		135.40	194.93	1.4738	.9235
1837	405	N. J.*	404	22.81	Straw	126.60	194.5	1.4729	.9250
1874	406	Tenn.*		18.62	Straw	127.6	193.6	1.4738	.9264
1976	407	Ala.*		23.29	Straw	126.8	192.6	1.4728	.9250
Average of 5 samples				20.83		128.5	194.15	1.4732	.9254

Series No. 500—(Guelph or Med. Green-Med. Early)									
1528	504	B. P. I.	17261	22.81		127.64	197.32	1.4726	.9207
1792	505	N. J.*	501	25.46	Straw	127.7	195.0	1.4731	.9240
1819	506	N. J.*	502	23.79	Dark	127.9	194.3	1.4730	.9249
1839	507	R. I.*		17.54	Straw	140.1	194.9	1.4745	.9270
1842	508	Ala.*	502	24.09	Straw				
1877	510	Penn.*		20.03	Amber	127.3	192.6	1.4715	.9300
1882	509	Tenn.*	502	21.82	Amber	126.3	193.3	1.4710	
1895	511	N. C.*	502		Dark	126.6	193.0	1.4730	.9230
1912	512	N. M.*	502	21.75	Dark	119.15	193.3	1.4720	.9260
1942	514	Ky.*	503-G	20.94	Dark	116.05	195.5	1.4718	.9238
1989	513	Iowa*	502	18.26	Amber	123.45	194.1	1.4730	.9261
2053	516	S. D.*	505	17.28		127.7	191.8	1.4725	.9240
2089	517	Mo.*	503-G	21.74	Dark	122.0	192.7	1.4722	.9270
Average of 12 samples				21.29		125.99	193.99	1.4725	.9251

Series No. 600—(Haberlandt)									
1812	607	N. J.*	602	24.60	Straw	137.5	191.7	1.4740	.9250
2065	611	Mo.*	604	19.62	Straw	129.9	192.0	1.4732	.9270
1820	606	N. J.*	601	22.27	Straw	136.2	194.8	1.4742	.9270
2091	610	Mo.*	603	20.46	Straw	129.0	192.3	1.4737	.9265
1940	608	Ky.*		19.63	Straw	120.9	192.7	1.4720	.9240
2092	612	Mo.*	605	22.19	Straw	131.4	191.0	1.4732	.9270
1944	608	Ky.*		19.64	Straw	121.0	193.45	1.4727	.9243
2121	613	Ky.*		20.36	Straw	133.2	192.8	1.4735	.9250
Average of 8 samples				21.10		129.19	192.59	1.4733	.9251

Series No. 700—(Peking)									
1827	705	N. J.*	701	20.20		137.1	193.1	1.4742	.9273
1830	704	N. J.*	702	20.90	Straw	135.8	194.25	1.4745	.9264
1834	703	N. J.*		21.09	Straw	137.5	194.5	1.4735	.9240
1892	706	Porto Rico*	702	18.65	Straw	127.8	195.5	1.4735	.9250
1945	707	Ky.*	17852-B	16.97	Straw	126.75	192.15	1.4728	.9240
2084	709	Mo.*	702	21.60	Straw	133.0	192.0	1.4740	.9290
2124	710	Ky.*		17.56	Amber	134.7	192.2	1.4734	.9250
Average of 7 samples				19.57		132.63	193.39	1.4737	.9258

Lab. No.	Reference No.	Grown in	From Seed	Crude Ether Extract	Color of Oil	Constancy of the Oil			
						Iodine No. Hanus	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
Series No. 800—Mongol. No samples									
Series No. 900—(Mikado)									
1975	903	Ind.*		18.62	Straw	128.55	193.5	1.4735	-----
Series No. 1000—(Wilson)									
1526	1003	B. P. I.	19185	20.45		135.16	196.92	1.4735	.9250
1513	1004	Ind.		19.82		126.68	193.48	1.4736	.9261
1824	1006	R. I.*	1002	19.05	Straw	138.1	192.0	1.4745	.927
1832	1005	N. J.*		23.13	Pale	134.8	195.27	1.4740	.9271
1841	1008	Ala.*	1002	20.32	Amber	117.4	194.4	1.4720	.9340
1844	1007	Md.*	1002	19.11		132.2	191.8	1.4740	
1870	1010	Penn.*		20.48	Straw	133.3	194.0	1.4740	.928
1876	1009	Tenn.*	1002	21.26	Straw	123.0	194.2	1.4711	.925
1881	1011	Penn.*	1002	20.11	Dark R	136.6	191.3	1.4745	
1897	1012	N. C.*	1002	17.82	L. Str.	117.4	192.3	1.4720	.926
1901	1013	N. J.*		21.46	Straw	132.8	192.1	1.4742	.927
1909	1016	W. Va.*	1002	18.60	Straw	133.2	194.5	1.4741	.9265
1914	1015	N. M.*	1002	20.32	L. Str.	123.8	193.5	1.4730	.9269
1941	1018	Ky.*		20.50	Dark	120.3	192.5	1.4720	.923
1958	1017	Iowa*	1002	18.19					
1962	1014	Md.*		20.68	L. Str.	130.3	193.7	1.4735	.9278
2088	1020	Mo.*	1003	21.26	Straw	128.7	191.1	1.4730	.9248
2131	1021	Ky.*		20.00	Dk. Str.	129.1	191.2	1.4728	.9230
Average of 18 samples				20.14		128.99	193.19	1.4733	.9256
Series No. 1100—(Sable)									
1978	1102	Ind.*		19.72	Straw	136.1	192.0	1.4740	.9249
Series No. 1200—(Holly Brook "Early")									
1563	1201	Kan.		19.45		118.59	195.45	1.4731	.922
1522	1202	B. P. I.	26838			127.36	195.79	1.4735	.9234
1810	1203	N. J.*	1201	20.91	Straw	137.1	191.7	1.4740	.9270
1872	1204	Va.*	1201	20.01	Straw	136.6	196.0	1.4740	.926
1937	1208	Ky.*		17.93		120.1	194.15	1.4720	.923
1961	1205	W. Va.*	1201	20.18	Straw	124.05	192.45	1.4728	.9238
1970	1207	Ala.*		20.54	Amber	121.9	194.9	1.4735	.929
1979	1206	Ind.*		16.79	Dark				
2077	1210	Conn.		19.99	Straw	136.7	191.1	1.4747	.9285
Average of 8 samples				19.48		127.81	193.94	1.4735	.9253
Series No. 1300—(Medium Yellow)									
1529	1301	B. P. I.	17269	20.22		132.31	197.09	1.4735	.9232
1796	1304	N. J.*		23.73	Lt. Str.	131.0	192.8	1.4740	.925
1829	1303	N. J.*	1302	22.27	Pale	127.2	194.4	1.4732	.926
1910	1305	Ill.*		18.01	Straw	129.2	194.6	1.4742	.927
2094	1306	Mo.*	1301	21.82	Straw	131.5	191.5	1.4735	.9270
Average of 5 samples				21.21		130.24	194.08	1.4737	.9256
Series No. 1400—(Amherst)									
1523	1401	B. P. I.	17275	20.94		131.71	195.51	1.4735	.9240
2090	1402	Mo.	1401	22.63	Straw	131.1	192.1	1.4735	.9270
Average of 2 samples				21.79		131.41	193.81	1.4735	.9255
Series No. 1500—(Elton)									
1521	1501	B. P. I.	20406	19.97		128.94	194.55	1.4730	.9224
Series No. 1700—(Jet)									
1530	1701	B. P. I.	17861	19.91		132.63	197.37	1.4735	

Lab. No.	Reference No.	Grown in	From Seed	Crude Ether Extract	Color of Oil	Constrance of the Oil			
						Iodine No. Hanus	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
Series No. 3000—(Early Black)									
		NONE							
Series No. 5300—(Sooty)									
		NONE							
Series No. 5400—(Arlington)									
2127	5401	Ky.*		17.77	Straw	134.5	191.7	1.4738	.9250
Series No. 5500—(White Eye Brow)									
		NONE							
Series No. 1600—(Tohas)									
1858 1531	16022 1601	N. J.* B. P. I.	21999	22.89 18.93	Straw	133.5 128.66	194.1 196.6	1.4735 1.4725	.9260 .9220
Series No. 1800—(Auburn)									
1799	1802	R. I.*		20.95	Straw	134.6	194.8	1.4740	.9264
Series No. 1900—(Brown)									
1831 1855	1903 1902	N. J.* N. J.*	1901	21.86 23.92	Straw Straw	131.6 131.5	193.1 194.15	1.4738 1.4736	.9260 .9270
Average of 2 samples				22.89		131.55	193.62	1.4737	.9265
Series No. 2000—(White Beans)									
1813	2003	N. J.*	2001	2.55					
Series No. 2100—(Morse)									
1800 1833 2125 1982	2102 2101 2105 2103	N. J.* N. J.* Ky.* Ind.*		23.09 24.85 22.05 19.69	Straw Straw	134.7 133.0 129.6 135.4	194.2 195.1 189.9 191.9	1.4740 1.4735 1.4730 1.4735	.9250 .9270 .9230
Average of 4 samples				22.42		133.17	192.77	1.4735	.9250
Series No. 2200—(Manchurian)									
1791 1801 1802 1804 1807 1811 1815 1822 1838 1840 1847 1856 1871 1873 1879	2207 2201 2209 2211 2203 2202 2210 2206 2212 2213 2204 2208 2216 2214 2218	N. J.* N. J.* N. J.* R. I.* N. J.* N. J.* N. J.* N. J.* R. I.* Ala.* N. J.* N. J.* Penn.* Tenn.* Maine*		18.45 25.13 28.93 23.11 27.02 24.92 24.22 24.08 22.89 22.38 24.45 24.93 21.07 22.84 17.92	Pale Pale Straw Pale Straw Straw Straw Straw Straw Straw Straw Straw Straw Straw Straw	131.8 130.3 128.4 132.5 128.4 129.5 130.1 131.4 133.8 128.6 129.65 129.6 122.1 141.9	193.15 194.75 192.2 191.2 195.0 195.2 194.4 192.5 193.1 194.2 195.0 195.0 193.4 193.4	1.4749 1.4730 1.4730 1.4737 1.4730 1.4738 1.4730 1.4730 1.4738 1.4731 1.4730 1.4730 1.4715 1.4747	.9282 .9238 .9230 .9240 .9220 .9260 .9270 .9270 .9270 .9260 .9270 .9270 .9260 .9280

Lab. No.	Reference No.	Grown in	From Seed	Crude Ether Extract	Color of Oil	Constancy of the Oil			
						Iodine No. Haas	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
Series No. 2200—(Manchurian)—Continued									
1884	2215	Va.*		22.14	Straw	126.5	194.1	1.4728	.9230
1885	2217	Utah*		19.59	Pale	129.95	194.0	1.4742	.9270
2050	2236	S. D.*	2203	20.37		132.4	191.1	1.4730	.9240
2070	2237	Mont.*	2203	21.16	Straw	133.8	190.1	1.4732	.9247
2083	2240	Mo.*		20.43	Straw	117.8	191.5	1.4722	.9260
2086	2239	Mo.*	2203	22.27	Amber	115.5	191.1	1.4719	
2087	2238	Mo.*	2202	22.49	Straw	117.9	190.7	1.4718	.9261
2093	2242	Mo.*		22.14	Straw	117.4	191.8	1.4721	.9240
2095	2241	Mo.*		22.06	Straw	119.8	191.5	1.4725	.9260
2128	2243	Mo.*		19.50	Straw	121.0	191.8	1.4720	.9220
1890	2220	N. C.*		22.55	Straw	127.5	193.6	1.4730	.9250
1893	2219	Porto Rico*		23.23	Straw	122.7	193.8	1.4720	.9260
1898	2221	N. J.*		22.17	Straw	131.2	193.7	1.4730	.9260
1911	2223	W. Va.*		21.00	Straw	128.3	192.1	1.4730	.9260
1913	2222	N. M.*		20.98		122.0	191.6	1.4720	
1949	2226	Ky.*		21.97	Straw	116.45	195.3	1.4715	.9230
1963	2224	Ala.*		19.41	Straw	128.2	195.2	1.4725	.9250
1965	2225	Iowa*		18.64		119.2	192.3	1.4720	
Average of 33 samples				22.10		126.64	192.99	1.4728	.9253
Series No. 2300—(Mercko)									
1853	2301	N. J.*		23.26	Straw	133.0	192.4	1.4734	.9259
Series No. 2400—(Ogema)									
1821	2401	N. J.*		25.13	Straw	128.08	194.0	1.4729	.9250
1843	2402	Mich.		17.29		126.5	192.4	1.4727	.9237
1988	2403	Idaho		15.24	Straw	129.9	192.7	1.4735	.9310
Average of 3 samples				19.22		128.16	193.03	1.4730	.9266
Series No. 2500—(Fairchild)									
1795	2501	N. J.*		23.49	Straw	128.8	192.8	1.4722	.9250
Series No. 2600—(O'Kute)									
1793	2601	N. J.*		27.05	Pale	126.5	194.4	1.4730	.9242
Series No. 2700—(Habero)									
1852	2701	N. J.*		23.05	Straw	129.3	192.2	1.4731	.9260
Series No. 2800—(Lowrie)									
1825	2801	N. J.*		22.27	Straw	130.9	194.7	1.4738	.9269
Series No. 2900—(Austin)									
1803	2901	N. J.*		20.84	Straw	132.5	194.0	1.4735	.9250
1947	2902	Ky.*		20.69	Straw	121.9	191.4	1.4725	.9240
Average of 2 samples				20.76		127.2	192.7	1.4730	.9245
Series No. 3100—(Chestnut)									
1790	3101	N. J.*		24.78	Pale	128.14	194.2	1.4734	.9240
Series No. 3200—(Columbia)									
1828	3201	N. J.*		23.41	Straw	130.3	193.2	1.4737	.9270
1952	3202	Ky.*		20.31	Dark	117.75	194.0	1.4716	.9250
Average of 2 samples				21.86		124.03	193.6	1.4726	.9260

Lab. No.	Reference No.	[Grown in	From Seed	Crude Ether Extract	Color of Oil	Constancy of the Oil			
						Iodine No. Hanus	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
Series No. 3300—(Brindle)									
1846	3301	N. J.*		22.43	Straw	128.7	193.2	1.4723	.9250
Series No. 3400—(Meyer)									
1805	3401	N. J.*		23.59	Straw	134.4	194.2	1.4738	.9240
2120	3403	Ky.*		20.07	Straw	128.7	192.5	1.4725	.9230
Average of 2 samples				21.83		131.55	193.35	1.4732	.9235
Series No. 3500—(Tashing)									
1849	3501	R. I.*		21.72	Dark	132.6	193.9	1.4734	.9261
1980	3502	Ind.*		22.32		126.5	194.4	1.4724	
Average of 2 samples				22.02		129.55	194.15	1.4729	
Series No. 3600—(Samarow)									
1835	3601	R. I.*		21.22	Dark	132.8	195.4	1.4738	.9270
Series No. 3700—(Chernie)									
1836	3701	R. I.*		19.22	Straw	135.6	195.3	1.4739	.9267
Series No. 3800—(Manhattan)									
1845	3801	R. I.*		18.37	Straw	134.4	193.6	1.4740	.9282
Series No. 3900—(Tokio)									
1875	3901	Tenn.*		18.99	Straw	130.8	194.3	1.4732	.9255
Series No. 4000—(Swan)									
1899	4001	N. J.		18.49	L. Str.	135.7	195.1	1.4745	.9265
1986	4002	B. P. I.	22379	19.27	Amber	133.9	194.4	1.4732	.9250
Average of 2 samples				18.88		134.8	194.75	1.4739	.9257
Series No. 4100—(Cloud)									
1900	4101	N. J.*		17.72	L. Str.	138.3	194.5	1.4745	.933
Series No. 4200—(Virginia)									
1984	4201	Md.*		19.95	Straw	137.15	193.1	1.4739	.9280
2130	4202	Ky.*		19.23	Straw	131.3	191.7	1.4735	.9240
Average of 2 samples				19.59		134.23	192.4	1.4737	.9250
Series No. 4300—(Flat King)									
1974	4301	Md.		20.07	Straw	135.3	192.9	1.4740	.9263
Series No. 4400—(Sherwood)									
1967	4401	Ind.*		18.47	Pale	131.6	192.4	1.4730	.9238

Lab. No.	Reference No.	Grown in	From Seed	Crude Ether Extract	Color of Oil	Constancy of the Oil			
						Iodine No. Hanus	Saponification at 25°C.	Refractive Index at 25°C.	Specific Gravity at 15.5°C.
Series No. 4500—(Early Brown)									
1981	4501	Ind.*		19.45		127.75	192.3	1.4722	
Series No. 4600—(Edward)									
1977	4601	Ala.*		21.71	Straw	128.7	196.1	1.4727	.9230
Series No. 4700—(Black Eye-brow)									
1987	4701	B. P. I.	30744	20.86	Straw	124.85	194.5	1.4723	.9235
Series No. 4800—(Mauchu)									
1973	4801	B. P. I.	80593	22.58	Straw	128.7	192.1	1.4730	
Series No. 4900—(Green)									
1985	4901	B. P. I.	30595	21.16	Straw	133.15	193.0	1.4734	.9250
Series No. 5000—(Quebec No. 92)									
1935	5001	McD.*Queb.		16.69	Straw	135.0	194.1	1.4750	.9270
2051	5002	S. Dak.*	5001	19.34		129.1	192.6	1.4728	.9240
2069	5003	Mont.*	5001	16.50	Straw	126.4	192.5	1.4730	.9244
2110	5004	McD.Queb.*		19.04	Straw	134.5	191.6	1.4740	.9270
Average of 4 samples				17.89		131.25	192.7	1.4737	.9256
Series No. 5100—(Quebec No. 537)									
1959	5101	McD.Queb.*		17.45	Straw	135.5	192.6	1.4735	.9260
2054	5102	S. Dak.*	5001	16.86		130.9	192.2	1.4730	.9260
2109	5103	McD. Queb.*		18.31		134.2	192.4	1.4732	.9230
Average of 3 samples				17.54		133.53	192.4	1.4732	.9250
Series No. 5200—(Brownies)									
1951	5201	Ky.*		16.03	D. Str.	127.2	191.6	1.4729	.9230
Special Series									
1808	4	N. J.*	17263	23.03		129.7	195.3	1.4747	.9270
1823	5	N. J.*	22927	24.05	Straw	129.3	194.5	1.4732	.9237
1854	6	N. J.*	22645	22.32	Straw	129.95	194.0	1.4730	.9250
1818	7	N. J.*	19183	23.19	Straw	133.1	191.9	1.4735	.9260
1850	8	N. J.*	17277	22.60	Straw	138.0	194.2	1.4740	.9270
1826	9	N. J.*	17862	21.03	Straw	137.3	195.2	1.4741	.9270
1817	10	N. J.*	17857	24.42	Straw	133.5	193.6	1.4735	.9260
1797	11	N. J.*	17852	20.70	Straw	134.8	193.1	1.4745	.9280
1964	13	Id.	1822	23.36	Pale	134.15	193.4	1.4738	.9265
1972	14	Ill.*		20.71	Straw	126.3	191.7	1.4730	.9253
1948	15	Ill.*		19.81	Straw	128.25	192.85	1.4734	.9260
1983	16	B. P. I.	30956	21.57	Straw	132.2	193.35	1.4730	.9240
1939	17	Ky.*	22645	18.44	Straw	118.45	193.05	1.4719	.9258
1936	18	Ky.*	22920	20.47	Straw	119.7	194.0	1.4723	.9245
1934	19	Ky.*	17852-C	16.43	Straw	124.0	191.9	1.4723	.9235
1943	20	Ky.*	19183-B	22.09	Amber	118.7	194.45	1.4720	.9255
1946	21	Ky.*	17852-E	18.15	Straw	122.9	194.0	1.4722	.9250
1950	22	Ky.*	22927	19.67	Straw	122.8	193.2	1.4723	.9255
1933	22	Ky.*	22927	18.26	Dark	121.7	191.8	1.4720	.9230
2122	25	Ky.*	22927	19.45	Straw	127.0	191.1	1.4725	.9230
2119	26	Ky.*	22920	20.82	Straw	129.4	192.5	1.4730	.9230
2123	27	Ky.*	17852-E	18.20	Amber	136.1	191.3	1.4735	.9250
2130	24	Ky.*	19183	19.74	Straw	128.3	191.0	1.4729	.9230
Average of 23 samples				20.80		128.5	193.1	1.4730	.9251

NOTE—1913 Crop denoted by * placed after state.
 1914 Crop denoted by * placed after state.

FLAX STUDIES

A number of samples of flax, received from the Botanical Department of the Station, representing various strains, have been examined as to the oil content, the drying quality of the same, the percent of protein, and other studies in connection with an investigation of linseed oil. The following table presents the principal data with regard to these points, together with the mean average for each class.

TABLE II. FLAX GROWN AT THE STATION
N. D. Resistant Flax No. 52.

Lab. No.	Botany No.	Moisture	Protein	Oil	Drying Quality
1009	14606	5.40	25.50	38.35	very good
1001	14611	4.93	25.57	34.12	excellent
991	14663	5.20	23.16	36.39	good
1002	14701	4.93	22.07	35.12	very good
1011	14749	4.93	24.88	33.73	good
1006	14767	4.66	24.75	35.35	good
992	14882	5.33	25.38	35.33	excellent
998	14917	4.93	25.61	34.84	very good
Mean—		5.04	24.61	35.40	

N. D. Resistant Flax No. 73.

990	14603	5.20	23.22	35.01	good
988	14748	4.93	23.16	37.22	good
1013	14805	4.80	23.84	35.83	very good
Mean—		4.97	23.40	36.02	

N. D. Flax No. 155.

984	14659	4.80	24.60	36.83	poor
1007	14677	5.23	21.56	40.65	good
1005	14789	5.06	23.04	36.32	very good
Mean—		5.08	23.07	37.93	

Minn. Flax No. 25.

995	14681	5.06	25.55	37.69	good
1012	14803	5.33	21.56	34.45	very good
1000	14956	4.66	25.05	38.47	good
Mean—		5.01	24.05	36.87	

N. D. Resistant Flax No. 114.

996	14709	5.40	25.22	34.02	good
987	14760	5.35	23.27	35.59	fair
994	14798	4.93	21.07	36.88	fair
993	14925	4.66	24.22	36.80	very good
1008	15692	5.20	21.66	38.83	good
Mean—		5.11	23.09	36.42	

Common Flax.

986	14601	4.80	21.01	38.69	fair
989	14639	4.93	20.74	41.18	good
1010	14654	5.20	26.27	34.94	good
985	14713	4.53	23.16	41.33	fair
1003	14729	5.20	24.75	34.10	excellent
997	14740	5.50	25.46	38.44	poor
1004	14818	5.00	24.57	34.30	good
999	14965	4.71	25.70	36.94	good
Mean—		4.98	24.00	37.49	

The means for the several classes of flax are shown as follows:

	Moisture	Protein	Oil
N. D. Resistant No. 52	5.04	24.61	35.40
N. D. Resistant No. 73	4.97	23.40	36.02
N. D. No. 155	5.03	23.07	37.93
Minn. No. 25	5.01	24.05	36.87
N. D. Resistant No. 114	5.11	23.09	36.42
Common Flax	4.98	24.00	37.49

IMMATURE FLAX SEED.

This lot represents an experiment with the variety of seed NDR—No. 114, grown on same ground and harvested at different dates—some harvested immature, others fully mature.

No. 47—Sample was pulled when bolls were green, August 20th. Seed variable in color, from black to green; very light weight; shrivelled; scaly; no comparatively plump seed present; no seed of normal color.

No. 48—Seed contains quite a large percentage of green, dark colored scaly seed, and a good deal of plump, bright colored normal seeds. Crop nearly ripe. Harvested August 31st.

No. 49—Seed is plump and bright colored. Some scale. Crop near maturity when harvested September 9th.

No. 50—Near full maturity when harvested September 15th. Seed approaching normal form. Some scale present. Color of plump seed rather characteristic of this variety. Scaly seed present due to immature bolls on the branches. Flowers were still present when harvested.

No. 51—Seed same lot as preceding. Contains some scale but the bulk of it is approximately of normal form. Harvested September 26th. The sample may be looked upon as approximately normal from a standpoint of maturity, as is the case with No. 50.

No. 52—This sample is the scaly seed blown off on the fanning mill, from a crop of No. 114, giving only scaly seeds; a large portion of these seeds being too immature, probably, to contain an embryo.

Unfortunately in a number of these samples there was not sufficient seed to enable us to secure the amount of oil so that full chemical data could be had. As far as determined, data is presented in the following table.

TABLE III. IMMATURE FLAX SEED
On Water-free Basis

Lab. No.	Moisture	Per cent Oil	Iodine No.	Saponification No.	Refractive Index at 25°C	Specific Gravity	Acid No.
47	5.89	38.77	185.49	192.60	1.4801		
48	5.67	38.04	185.46	192.38	1.4796	.9330	2.80
49	7.30	38.70					
50	7.34	36.79	175.92	192.36	1.4787	.9310	0.54
51	5.80	40.78					
52	6.01	39.75	185.97	191.90	1.4795	.9336	2.00
Av.	6.33	38.80	183.21	192.31	1.4795	.9325	1.78
Max.	7.34	40.78	185.97	192.60	1.4801	.9336	2.80
Min.	5.67	36.79	175.92	191.90	1.4787	.9310	0.54

CHEMICAL CONSTANTS FOR LINSEED OIL.

A good opportunity has been afforded for determining some of the chemical constants in linseed or flax seed oil from samples of flax of good quality from the crop of 1914.

In the following table is presented the data for a series of rather high grade flax seeds, all of which were submitted in the Improved Seed Growers Contest, January, 1915, and, therefore, had been selected by the Growers as flax of sufficient quality to entitle the same to a place in the exhibition.

The samples came from various portions of the state and the following comments and data are taken from the records of the committee that judged the quality of the flax.

TABLE IV. FLAX SEED

Serial No.	Variety	Weight per bu.	Color	Quality
53	73	53.75	Normal	Some scaly
54	52	51.50	Normal	Scale present
55	73	53.25	Dark	Frosted before ripe
56	114	53.	Nearly Normal	Shrunken some—scale
57	52	55.	Bright, light	Small, some scale
58	52	53.	Grayish to dark	Some scaly
59	52	53.50	Nearly Normal	Some scaly
60	155	52.	Fair	Small, shrunken
61	52	53.50	Grayish	Some scaly
62	114	54.	Light, straw	Small, shrunken
63	52	56.25	Light	Small, immature
64	114	54.	Normal to dark	Some scale
65	114	56.50	Normal dark	Small plump
66	52	55.	Normal	Plump
67	114	53.	Normal to dark	Some immature scaly
68	52	53.	Normal	Slightly scaly
69	52	54.	Extra light	Slightly shrivelled
70	Common	52.50	Normal	Nearly plump
71	114	54.	Too dark	Some immature—scale
72	73	54.	Normal Brown	Some scaly
73	22	52.	Nearly Normal	Some scaly
74	114	55.	Nearly Normal	Nearly Normal
75	114	54.	Normal	Normal
76	Minn. 25	53.	Half Dark	Immature, scaly
77	52	53.	Color off by scale	Considerable scale
78	155	51.	Color off by scale	Considerable scale
79	114	55.50	Nearly Normal	Nearly plump
80	52	50.25	Nearly Normal	Normal plump—Very dry
81	155	53.	Dark brown	Nearly Nor., some immat.
82	52	53.75	Light, straw	Some thin immature
83	52	53.50	Normal	Some young, dark grains
84	155	51.	Gray from Normal	Some scaly
85	Common	54.	Nearly Normal	Nearly Normal
86	Common	54.	Nearly Normal	Nearly Normal
87	Minn. 25	53.50	Nearly Normal	Nearly Normal
88	155	54.75	Light, straw	Nearly Normal
89	Common	55.50	Light—nearly Normal	Nearly Normal
90	Common	52.75	Nearly Normal	Some green seeds
91	Common	53.	Light to straw	Nearly Normal
92	Common	54.	Light & dark seed mixture	Immat. green to black seed
93	Common	51.	Gray from Normal	Nearly Normal
94	114	54.75	Nearly Normal	Small, some shrunken
95	Minn. 25	53.	Nearly Normal	Some dark green thin, im.
96	Minn. 25	54.	Nearly Normal	Small, some green
97	Minn. 52	53.	Light to straw	Small, some green
98	52	55.50	Nearly Normal	Some black green
99	114	54.25	Rather light	Nearly Normal, small
100	52	55.	Greenish cast	Nearly Normal
101	52	54.25	Nearly Normal	Some scaly

The entries under the titles "Color" and "Quality" are briefly listed terms to indicate inspection observation on the color and qual-

ity of the sample but do not necessarily indicate any great degree of scaliness,—immaturity or shrunkenness.

Green or black seeds are usually occasioned by the seed being immature at harvest or frost time. Those samples that are marked "scaly" may be due to disease or to drying up of the plants due to drouth, but more specifically to disease.

Taken as a whole, however, the lot may be considered as a normal lot of flax.

The chemical constants for these various samples are shown in the accompanying table:

TABLE V. OIL FROM HIGH GRADE FLAX SEED
On Water-free Basis

Lab. No.	Moisture	Per cent Oil	Iodine No.	Saponification No.	Refractive Index at 25°C	Specific Gravity	Acid Number
53	6.91	38.95	190.02	191.02	1.4799	.9330	0.60
54	6.63	39.63	187.73	191.12	1.4796	.9340	0.81
55	7.17	37.55					
56	6.23	38.67	171.55	190.65	1.4781	.9310	0.63
57	6.24	42.42	193.12	191.60	1.4795	.9340	0.71
58	6.40	41.95	186.15	191.60	1.4795	.9330	1.20
59	7.10	39.59	192.00	190.70	1.4805	.9340	0.78
60	6.26	41.00	182.65	191.85	1.4792	.9327	0.89
61	6.65	41.32	192.95	191.60	1.4805	.9345	0.61
62	7.14	38.67	186.65	191.55	1.4795	.9335	0.97
63	6.16	40.88	182.75	191.15	1.4790	.9320	0.77
64	6.54	40.11	193.32	191.28	1.4802	.9335	0.87
65	6.45	40.43	194.15	191.94	1.4804	.9340	1.00
66	6.63	40.83	191.11	191.70	1.4803	.9340	0.50
67	6.25	37.60	183.20	192.85	1.4790	.9330	0.78
68	6.40	38.80	188.65	192.15	1.4802	.9330	1.23
69	6.42	42.21					
70	6.99	38.25	188.35	191.60	1.4798	.9332	0.75
71	6.70	39.68	189.50	190.85	1.4798	.9340	0.60
72	6.65	37.52	187.25	191.60	1.4800	.9335	0.65
73	6.72	38.15	180.55	191.60	1.4792	.9330	1.33
74	6.53	39.85	188.40	192.10	1.4799	.9330	0.84
75	7.09	38.15	182.65	191.60	1.4798	.9330	2.50
76	6.50	39.79	184.23	191.92	1.4794	.9330	0.55
77	6.75	37.98	188.00	190.70	1.4795	.9330	1.07
78	7.43	36.63	177.05	190.55	1.4790	.9320	0.53
79	6.28	37.17	182.70	191.00	1.4794	.9335	
80	5.97	39.23	183.50	191.20	1.4795	.9330	0.69
81	7.10	37.21	183.70	191.25	1.4792	.9330	0.80
82	6.43	37.31	184.75	191.45	1.4799	.9330	0.85
83	6.50	39.69	187.40	192.50	1.4795	.9335	1.62
84	6.83	41.33	188.30	191.55	1.4801	.9335	1.86
85	6.35	38.13	184.35	191.78	1.4795	.9327	0.88
86	7.16	39.87	191.55	190.25	1.4805	.9340	0.67
87	7.04	38.59	189.63	190.12	1.4801	.9340	0.64
88	6.77	41.37	187.03	191.18	1.4798	.9340	0.87
89	6.40	41.39	188.20	191.05	1.4800	.9330	0.90
90	6.77	38.90	193.59	190.70	1.4792	.9335	0.65
91	6.81	38.78	185.90	190.03	1.4795	.9324	0.83
92	6.79	40.28	177.65	190.88	1.4786	.9315	0.38
93	6.50	38.07	187.85	192.37	1.4798	.9335	0.81
94	6.26	41.45	184.80	191.55	1.4797	.9328	1.11
95	7.46	37.94	179.47	189.89	1.4787	.9320	0.53
96	6.50	39.25	187.05	191.30	1.4799	.9338	1.27
97	6.38	34.34	177.00	191.35	1.4788	.9310	3.10
98	6.95	42.27	191.35	191.95	1.4800	.9340	0.68
99	7.27	38.67	184.90	190.60	1.4797	.9325	0.74
100	6.99	40.40	177.90	191.00	1.4790	.9317	1.82
101	7.12	38.49	187.65	191.90	1.4800	.9330	0.88
Mean	6.67	39.32	185.92	191.29	1.4796	.9331	0.95
Max.	7.46	42.42	193.12	192.85	1.4805	.9345	3.10
Min.	5.97	36.63	171.55	189.89	1.4788	.9310	0.38

FLAX GROWN UNDER LIKE CONDITIONS.

The following samples were from flax grown on the Station grounds in 1914 in what is known as the "slough field", or field N. The samples were all planted on the same day and harvested at practically the same time and were equally ripe, so that the results are comparable, although they were grown from seed secured from farmers throughout the state and were not necessarily of the same variety or strain.

TABLE VI. FLAX GROWN UNDER LIKE CONDITIONS
On Water-free Basis

Lab. No.	Moisture	Per cent Oil	Iodine No.	Saponification No.	Refractive Index at 25°C	Specific Gravity	Acid Number
1	7.91	32.50	181.07	192.82	1.4799	.9345	5.10
2	6.96	38.41	187.27	192.15	1.4804	.9335	1.27
3	8.29	29.52	179.95	191.45	1.4795	.....	.....
4	7.04	38.63	188.21	190.83	1.4804	.9340	.....
5	7.15	38.15	188.53	192.64	1.4804	.9345	1.83
6	7.54	38.23	190.36	193.28	1.4806	.9340	2.73
7	7.36	39.27	187.84	190.68	1.4804	.9340	1.00
8	6.87	38.64	190.21	191.52	1.4800	.9335	0.83
9	7.20	37.84	187.28	191.42	1.4795	.9325	1.26
10	7.22	38.98	195.49	191.44	1.4812	.9355	1.29
11	6.95	39.64	196.63	191.28	1.4811	.9345	0.99
12	6.79	37.54	189.94	192.94	1.4802	.9335	1.14
13	7.72	38.65	189.64	191.27	1.4802	.9347	0.95
14	7.43	38.77	.....	.....	.....	.....	.....
15	7.25	38.92	192.10	190.30	1.4809	.9346	.....
16	7.25	39.62	192.35	192.86	1.4805	.9340	1.09
17	6.89	37.78	189.54	191.40	1.4803	.9335	0.71
18	6.95	37.63	187.37	191.35	1.4800	.9340	0.77
19	6.98	37.79	186.65	192.46	1.4798	.9340	0.70
20	5.92	38.48	188.50	192.83	1.4794	.9340	2.16
21	5.67	40.53	184.97	192.70	1.4810	.9335	2.03
22	5.96	38.15	185.25	192.60	1.4808	.9325	1.13
23	5.90	39.85	180.30	191.95	1.4798	.9330	.....
24	5.82	37.62	182.70	193.50	1.4810	.9320	1.86
25	5.96	38.34	185.64	192.40	1.4808	.9325	0.73
26	5.83	40.71	185.88	192.78	1.4796	.9340	3.32
27	5.97	37.56	.....	.....	.....	.....	.....
28	5.54	40.50	183.89	192.04	1.4795	.9335	1.82
29	6.17	37.27	.....	.....	.....	.....	.....
30	5.81	40.72	.....	.....	.....	.....	.....
31	7.42	37.16	182.40	191.23	1.4791	.9330	1.40
32	7.55	37.71	186.40	192.12	1.4802	.9340	1.19
33	5.86	40.74	184.65	192.25	1.4796	.9337	2.17
Mean	6.71	38.24	187.07	191.55	1.4802	.9337	1.56
Max.	8.29	40.74	196.63	193.50	1.4812	.9347	5.10
Min.	5.54	29.52	179.95	190.68	1.4791	.9320	0.70

FLAX, WET, AFTER HARVEST.

A number of samples of flaxseed have been examined, taken from crops that had been allowed to become badly wet and to some extent injured after the same had been harvested. The records for these samples are as follows:

No. 34. Knudson's No. 1B—(Harvested so as not to allow the introduction of moisture.)

No. 35. Knudson's No. 1C—(Not moulded in the straw after cutting.)

No. 36. Knudson's No. 1CM—(Moulded in the straw after cutting.)

No. 37. Knudson's No. 1D—(Not moulded in the straw after cutting.)

No. 38. Knudson's No. 1DM—(Moulded in the straw after cutting.)

No. 39. Knudson's No. 1E—(Not moulded in the straw after cutting.)

No. 40. Knudson's No. 1EM—(Moulded in the straw after cutting.)

- No. 41. Knudson's No. 1F—(Not moulded in the straw after cutting.)
 No. 42. Knudson's No. 1FM—(Moulded in the straw after cutting.)
 No. 43. Knudson's No. 1G—(Not moulded after cutting.)
 No. 44. Knudson's No. 1GM—(Moulded in the straw after cutting.)
 No. 45. Knudson's No. 1H—(Not moulded in the straw after cutting.)
 No. 46. Knudson's No. 1HM—(Moulded in the straw after cutting.)

While the season of 1914 was abnormal at harvest time, there being little moisture, rain and dew, therefore, the moulding of the samples was not excessive. On the straw and bolls there was a good deal of mould, but when threshed the seed remained almost equivalent in appearance to samples not exposed to moisture. The flax that was out is perhaps somewhat darker.

The data for the samples, as far as there was material, is shown in the following table:

TABLE VII. FLAX, WET, AFTER HARVEST
On Water-free Basis

Lab. No.	Moisture	Per cent Oil	Iodine No.	Saponification No.	Refractive Index at 25°C	Specific Gravity	Acid Number
34	7.67	37.89	184.7	190.35	1.4795	.....	.....
35	5.95	38.98	185.02	192.10	1.4802	.9330	1.22
36	7.38	40.21	182.69	193.54	1.4800	.9345	.....
37	7.14	40.74	.....	.....	.....	.....	.....
38	6.93	37.41	182.63	190.05	1.4795	.9330	1.35
39	5.83	40.49	184.94	191.05	1.4796	.9330	2.57
40	7.30	38.24	186.35	192.10	1.4798	.9330	.....
41	5.98	37.71	.....	.....	.....	.....	.....
42	5.85	41.29	175.83	191.81	1.4787	.9315	2.97
43	5.96	36.23	181.34	192.96	1.4792	.9330	1.70
44	6.09	38.86	.....	.....	.....	.....	.....
45	5.73	40.53	184.24	191.82	1.4793	.9335	1.66
46	6.07	37.57	184.02	192.98	1.4796	.9330	1.75
Mean	6.45	38.93	183.17	191.87	1.4795	.9331	1.89
Max.	7.67	41.29	186.35	192.98	1.4802	.9345	2.97
Min.	5.83	36.23	175.83	190.05	1.4785	.9315	1.22

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35

North Dakota Agricultural Experiment Station

North Dakota Wheat for 1916

By E. F. Ladd

Bulletin No. 119

Agricultural College, North Dakota
NOVEMBER, 1916

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* Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

NORTH DAKOTA WHEAT FOR 1916

By E. F. LADD

Two bulletins have been published containing information with regard to wheat matters, namely, Special Bulletin No. 14, Volume 3, "Is the Present System of Grading Wheat Equitable?", and Bulletin No. 114, "Chemical and Physical Constants for Wheat and Mill Products", which have brought repeated demands for information with regard to the milling and bread-producing qualities of the wheat crop for 1916. It is decided, therefore, to publish the data for the 1916 samples thus far milled, giving more detailed and complete information on the completion of the year's experiments which cannot be finished before mid-summer. The writer is responsible for the presentation of the matter, while all of the milling and grading results are furnished by Thomas Sanderson, and the analytical and baking results by Levi Thomas and W. L. Stockham.

Wheats at the terminal markets of Minnesota are graded in accordance with the Minnesota grades as prepared by the Board of Grain Appeals at Minneapolis and the Board of Grain Appeals at Duluth. From an official publication we quote the following for Northern Spring Wheat, also, for Durum Wheat.

"NORTHERN SPRING WHEAT."

"No. 1 Hard Spring Wheat—Shall be dry, sound, bright, sweet, clean and consist of over 75 per cent of the hard kernels and weigh not less than 58 pounds to the measured bushel.

"No. 1. Northern Spring Wheat—Shall be dry, sound, sweet and clean may consist of the hard and soft kernels of spring wheat and weigh not less than 57 pounds to the measured bushel and shall not contain to exceed one-half of 1 per cent of wild vetch (wild pease) or kingheads, singly or combined, and not to exceed a total of 1 per cent of inseparable weed seed.

"No. 2 Northern Spring Wheat—Shall be dry, spring wheat, not clean enough or sound enough for No. 1, but of good milling quality and must weigh not less than 56 pounds to the measured bushel, and shall not contain to exceed 1 per cent of wild vetch (wild pease) or kingheads, singly or combined, and not to exceed a total of 2 per cent of inseparable weed seed.

"No. 3 Northern Spring Wheat—Shall be composed of inferior, shrunken spring wheat and weigh not less than 54 pounds to the measured bushel, and shall not contain to exceed 2 per cent of wild vetch (wild pease) or kingheads, singly or combined, and not to exceed a total of 4 per cent of inseparable weed seed.

"No. 4 Northern Spring Wheat—Shall include inferior spring wheat that is badly shrunken or damaged and weight not less than 49 pounds to the measured bushel.

"Sample Grade Spring Wheat—Shall include all varieties of inferior spring wheat, that is badly sprouted, very musty, badly bin burnt, fire burned, badly damaged containing live weevil or otherwise unfit for higher grades.

"No-Grade Wheat—All spring and durum wheat containing 15 percent or more of moisture, or in a heating condition or otherwise unfit for store, shall be classed no grade, with inspector's notation as to what grade same would be if in condition. For example: NG No. 1, NG No. 2, NG No. 3, etc.

"Note—Hard, flinty wheat of good milling quality and containing no appreciable admixture of soft wheat may be admitted into the grades of No. 2 Northern spring wheat, No. 3 Northern spring wheat, and No. 4 Northern spring wheat, provided weight of the same is not more than one pound less than the minimum test weight required by the existing rules of said grades, and provided, further, that such wheat is in all other respects qualified for admission into such grades.

"Note—The variety of wheat known as 'humpback', owing to its inferior milling quality, shall not be graded higher than No. 3.

"Note—The percentage of inseparable weed seed as stated above shall be carried only when the wheat is of sufficiently superior quality to justify these additional defects."

"DURUM (MACARONI) WHEAT."

No. 1 Durum Wheat—Shall be bright, sound, dry, well cleaned and be composed of durum commonly known as macaroni wheat and weigh not less than 60 pounds to the measured bushel.

"No. 2 Durum Wheat—Shall be dry, clean, and of good milling quality. It shall include all durum wheat that for any reason is not suitable for No. 1 Durum and weigh not less than 58 pounds to the measured bushel.

"No. 3 Durum Wheat—Shall include all durum wheat bleached, shrunken, or for any reason unfit for No. 2 and weigh not less than 55 pounds to the measured bushel.

"No. 4 Durum Wheat—Shall include all durum wheat that is badly bleached or for any cause unfit for No. 3.

"Note—Red-berried durum, western soft durum, owing to their inferior milling quality, shall not be graded higher than No. 3.

"Note—The percentages of inseparable weed seed established for Nos. 1, 2 and 3 Northern Spring wheat shall also apply to Nos. 1, 2 and 3, Durum wheat.

"Mixed Wheat—Eight per cent or more of spring wheat in Durum, Winter or Western White or Red Wheat and 4 per cent or more of Durum, Winter or Western White or Red Wheat in spring wheat shall be graded Nos. 1, 2, 3, etc., MIXED WHEAT."

It will thus be observed that only five grades are fixed for the wheats and in addition "sample grade" and "no grade"; "no grade" of course representing wheat in bad condition. The sales, therefore, in the terminal market in Minneapolis, for example, are assumed to be made on these grades, but it would appear that the grading of the wheat, as carried out at the point of purchase in North Dakota, is in accordance with instructions sent out from day to day from Minneapolis, as shown by the following from a notification postal card sent out regularly to the buyers of wheat.

Minneapolis, Minn.

Oct. 14, 1916.

"This cancels card of 13"

	lbs.	
Wheat No. 1 Nor.	57	158
Wheat No. 2 Nor.	56	154
Wheat No. 3 Nor.	54	148
Wheat No. 4 Nor.	53	136
Wheat No. 4 Nor.	52	130
Winter Wheat No. 2		144
Winter Wheat No. 3		138
Durum No. 1	60	160
Durum No. 2	58	156
Durum No. 3	55	144

Durum No. 4	54	127
Durum No. 4	52-53	115
Sample Feed Spring No. 4	49-51	124
Sample Feed Spring A	47-48	114
Sample Feed Spring B	45-46	99
Sample Feed Spring C	43-44	89
Sample Feed Spring D	35-42	79
Feed Durum No. 4	50-51	102
Feed Durum A	48-49	93
Feed Durum B	46-47	83
Feed Durum C	44-45	73
Feed Durum D	40-43	63

Nor. 36

The Grain Bulletin

The official body establishing these grades and prices is not given on the cards as they go out from Minneapolis to the dealer. It will be noticed that the grading according to this card is quite different from the official grades and does not conform with regard to test weight per bushel.

There are several additional grades,—Grade 4, No. 2 and Grade 4, No. 3; and in addition to these a classification is made as "Feed A", "B", "C", and "D".

No matter what the grade may be at the point of purchase the terminal grade is assumed to be one of the five as indicated in the official announcement from the Board of Grain Appeals. Therefore, No. 4-No.2, and No. 4-No. 3 and a part of Feed A should sell as No. 4°. The balance of Feed A as well as Feeds B, C, and D, will all be sold as sample grade if sold under the official classification.

It may be also assumed that the term "Feed" is intended to imply that the wheat had no milling value, but is to be used exclusively for feed purposes. The milling tests together with the baking tests will, therefore, prove of special interest in this connection. The milling was done on the small two-stand mill. The samples were sent in from various parts of the state, some from individual farmers, from county agricultural agents, elevators, demonstration farms, etc. The number of samples in the higher grades are rather limited, but having no choice in the matter we have used them as received.

As already indicated the grading is based on a card or price-list sent out to the local elevators by the Grain Bulletin from Minneapolis, and is the elevator's instructions regarding grade and price until there is received a renewal with the market changes. This card is more stringent regarding the higher grades than the grading rules issued by the Minnesota Grain Inspection Department since there are grades which the rules make no provision for at all. Therefore, the wheat would appear to be bought from the farmer by one set of rules or system of grading and sold to the terminal elevator by an entirely different system of grading if we are to judge from the information available to us. The price as quoted on the card is made apparently on the test weight per measured bushel but requires sixty pounds of wheat in each case to constitute a bushel as sold. In our comparison as a basis for the market value, we take the average of the high and low cash market at Minneapolis, as quoted by the Northwestern Miller

for 6 days, Oct. 11-17 inclusive. Using this average price as far down as the grades apply or correspond to the grades as shown by the card, and then using the same spread in price between No. 1°, as is shown by the card, we get the market price for all the other grades as follows:

MARKET PRICE

Average of high and low and averages for Oct. 11-17 inclusive.
From page 173 Northwestern Miller.

	Hard	Red Spring	Durum
No. 1 Northern	1.732		1.806
No. 2 Northern	1.704		1.760
No. 3 Northern	1.626		1.6112
No. 4 Northern	1.403	not quoted	
Sample grade	1.2777	not quoted	
No grade	1.4139	not quoted	

If we base our values on No. 1 Northern with the same spread in value as shown on the card sent to the local elevators by the Grain Bulletin, then we have the following:

Grade	Hard	Red Spring	Durum
No. 1 Northern	1.732		1.806
No. 2 Northern	1.704		1.760
No. 3 Northern	1.626		1.6112
No. 4 Northern	1.51		1.47
No. 4 Northern	1.45		1.35
No. 4 Northern	1.39		1.22
A feed	1.29		1.13
B feed	1.14		1.03
C feed	1.04		.93
D feed	.94		.83

If we deduct from the above figures the freight-rate per bushel for any grade to the Minnesota transfer, we should then have the local value of the wheat or from Fargo approximately 7 cents per bushel.

The market quotations for flour during the same period, according to the Northwestern Miller, ending Oct. 17, 1916, were as follows:

Straight Flour, per 100 lbs.	\$4.426
Bran, per 100 lbs.	1.156
Shorts and other products per 100 lbs.	1.567
Screenings, per 100 lbs.	.675

The foregoing prices are for wholesale or carload lots and based upon the market price at Minneapolis. The above values are used throughout in the calculations for these tables.

It will be observed that the majority of the samples for this year are falling under the classification of "Feed" grades, and there is in our series no No. 4 Northern, although there are a few samples of the higher grades. The large proportion of the lower grades of wheat makes the grading of the milling value of the wheat an important matter this year.

The tables from 1 to 9 show clearly for themselves the facts concerning the several grades examined.

Lab. No. W

3084	Li
3085	Li
Avr.	.....
Max.	.....
Min.	.....

2988	Ca
2990	Sn
Avr.	.....
Max.	.....
Min.	.....

3079	M
3088	B
3242	L
3293	B
Avr.	.....
Max.	.....
Min.	.....

2987	C
3080	B
3248	B
3292	B
Avr.	.....
Max.	.....
Min.	.....

3109	.....
3190	.....
3243	.....
3286	.....
Avr.	.....
Max.	.....
Min.	.....

3081	.....
3083	.....
3087	.....
3100	.....
3116	.....
3156	.....
3161	.....
3165	.....
3217	.....
3294	.....
Avr.	.....
Max.	.....
Min.	.....





WHAT THE DATA SHOWS:

A study of the tables will show, from a milling point of view, that the percent of flour from No. 1 and No. 2 Northern is fairly high and compares favorably with the results obtained at this Station in other years, although the number of samples represented are limited and might run, in a larger series, somewhat different. The samples in No. 3 and No. 4 Northern grades are a little low in percent of flour compared with the same grades in other years; while in the so-called "Feed" grades we have had very few samples in other years with which to make a comparison.

We find in the No. 3 and No. 4 Northern grades a test weight, before cleaning, of 55 pounds to 49 pounds, and we have the percent of flour ranging from 69.03 to 63.01, with the lowest average of any grade 65.18 percent; in the feed grades a range from 67.78 to 50.23 percent, with the lowest average in any grade 60.40 percent. Between the maximums of all grades there is a spread in percent of flour from 73.07 in Table II, sample 2990 to 50.32 in Table IX sample 3289. If we assume that the flour from these two samples is of equal baking quality (the baking results show they are), then the flour should be of equal value, and figuring the difference in percent of flour to be 22.75 at the value as shown of \$4.426, the difference would be \$1.00 or 60 cents per bushel. The sample giving the high percent of flour, being No. 2 Northern, market value \$1.704, would make the sample giving the low percent of flour worth \$1.104 or 16.4 cents more than the market value when based on the flour percent alone. When we consider, for these two samples, the value of the mill products, we find a difference of 33.72 cents which would give a market value per bushel of \$1.374 or 43.4 cents per bushel more than the market value when compared with the No. 2 sample. Ignoring the dockage in either case there would be a difference in value of 43.78 cents per bushel or for No. 2 Northern, value \$1.704 less 43.78 cents, equals \$1.262 or 32.62 cents per bushel more than market value.

BAKING RESULTS:

A study of the data presented in the baking results will show that these samples can be blended together in almost any quantity and the flour would make a good bread. By eliminating some of the poor samples or by adding more of the good samples a choice flour could be produced. As a matter of fact, the large mills all blend wheats to get the desired results for color, texture and loaf volume. All these wheats are good and in general show large loaf volume and good texture, but not always standard in color, sometimes quite inferior in color which would not seriously affect the blend and would add much in strength, for the gluten content is exceptionally good.

GENERAL AVERAGES:

If we take the general averages for the several grades as presented in the tables and bring together the data for comparison, both with regard to the milling and baking tests, we shall find that the percent of flour is much higher for the lower grades than is generally assumed. If we examine the loaf volume we note that for the lower grades the volume is much higher than for the higher grades; while the color averages the equal of the minimum standard for straight flours. The same is true for the texture, although it does not equal that of the higher grades, and show the advantages that would come from being blended with other flours. The data for the combined averages is as follows:

TABLE XV. THE AVERAGES:

	No. 1	No. 2	No. 3	No. 4 (2)	No. 4 (3)	FEED			
						A	B	C	D
Weight uncleaned	57.5	56.0	54.4	52.1	49.2	47.4	45.0	43.3	37.9
Weight cleaned	60.5	58.5	58.7	56.1	54.2	53.4	50.8	49.6	46.7
Screenings	3.37	3.96	6.23	6.57	6.77	9.24	11.51	8.43	17.34
Flour, percent	69.63	72.64	65.44	65.18	65.68	63.72	63.39	62.9	60.40
Bran, per cent	16.27	14.30	12.57	12.90	15.88	15.98	17.76	17.35	19.04
Shorts, percent	13.53	13.69	20.76	21.44	18.41	20.41	19.04	19.11	19.69
Loaf volume, c. c.	2317	2292	2291	2304	2522	2314	2471	2734	2677
Color	93.7	93.2	91.5	91.0	91.0	88.6	88.9	92.3	84.3
Texture	93.0	94.2	90.5	90.2	89.2	88.3	89.0	93.6	91.5

In the same manner if we bring together the receipts for the mill products as compared with the cost for the wheats, we shall get a better idea of the relative value and of the gain in percent, or, undoubtedly, the comparative profits for handling the several grades of wheat, as follows:

TABLE XVI. THE RECEIPTS PER BUSHEL

	No. 1	No. 2	No. 3	No. 4 (2)	No. 4 (3)	FEED			
						A	B	C	D
The Cost	\$1.732	\$1.704	\$1.626	\$1.45	\$1.39	\$1.29	\$1.14	\$1.04	\$0.94
Receipts:									
Screenings	0.0136	0.0160	0.0252	0.0260	0.0274	0.0374	0.0466	0.0359	.0702
Flour	1.8494	1.9290	1.7378	1.7309	1.7442	1.662	1.6834	1.6696	1.6040
Bran	0.1129	0.0992	0.0872	0.0895	0.1101	0.1108	0.1232	0.1203	0.1321
Shorts	0.1272	0.1287	0.1952	0.2016	0.1731	0.1919	0.1790	0.1797	0.1851
Total	\$2.1031	\$2.1729	\$2.0454	\$2.0486	\$2.0548	\$2.0323	\$2.0322	\$2.0055	\$1.9914
Increase	0.3711	0.4689	0.4194	0.5986	0.6648	0.7423	0.8922	0.9655	1.0514
Gain %	21.4	27.5	25.8	41.1	47.8	57.5	78.2	92.8	111.9

RELATIVE PROFITS:

In examining the table above we note that the percent of flour produced by the grades of wheat Nos. 3, 4 (2) and 4 (3) are essentially the same or above sixty-five percent and, therefore, presumably are of equal value for flour production; while in bread production they show a larger loaf volume than the higher grades and are but slightly inferior in color. Four classes of wheats grade as Feed A, B, C, and D all produce above sixty percent of flour on the average for the entire series and it is not to be assumed that a product of as much value as this for flour production will be used as cattle feed. When

we examine the bread made from these flours we find a better average loaf volume than for any other class as would be expected from the gluten content, and the color and texture averages well. The interesting feature comes, however, it seems to me, in considering the increase in percent of the sales price for the mill products as compared with the cost for the wheat. This can best be summarized again as follows:

TABLE XVII. COMPARISON OF COST OF WHEAT AND RECEIPTS FROM MILL PRODUCTS

	Cost of wheat	Receipts from mill products	Percent of gain
No. 1 Northern	\$1.732	\$2.1031	\$21.4
No. 2 Northern	1.704	2.1729	27.5
No. 3 Northern	1.626	2.0454	25.8
No. 4 (2)	1.45	2.0486	41.1
No. 4 (3)	1.39	2.0548	47.8
Feed A	1.29	2.0323	57.5
Feed B	1.14	2.0322	78.2
Feed C	1.04	2.0055	92.8
Feed D	.94	1.9914	111.9

Clearly if there is a profit in milling high grade wheats; No. 1 and No. 2 Northern this year, when the gain is 21.4 percent and 27.5 percent, then certainly in the lower grades where for No. 4 (3) there is a gain of 47.8 percent and in Feed C. 92.8 percent and in Feed D 111.9 percent, then there certainly should be a net profit for the feed wheats much in excess of that made on the high grade wheats and would indicate their relatively greater value than is shown by the purchase price. These figures, of course, do not show the cost of manufacture or legitimate profits; they are only intended to be accurate data with regard to the total proceeds from the sale of the various products as compared with the cost of the original material.

A CAR-LOAD OF WHEAT.

For convenience let us take a carload of wheat for the several grades and follow it through from the North Dakota farmer to the terminals and the milling portions back again through to retail trade to the consumer who may have been the farmer who produced the wheat itself. This will give us a better means of comparison and one that can be easily understood and followed.

Nine of the ten grades are represented in the tables presented in this bulletin. There were no samples with the proper weight per measured bushel to make a first No. 4 Northern grade. It should be borne in mind that these grades do not conform to the Minnesota Grain Inspection Rules which provide for seven grades for Hard Red Spring wheat. The grades as shown on the card, therefore, are arbitrary and only apply when the farmer sells his wheat to the local elevator company or other dealer employing this same system of grading. For a comparison of the grades and values we will offer the following giving the local grade and weight per bushel and value as shown by the card of Oct. 14, 1916, followed

by the Grain Inspection Department grades, weight per bushel and average value at Minneapolis for the week ending Oct. 17, 1916.

TABLE XVIII. COMPARISON OF LOCAL GRADES AND VALUES WITH GRADE AND VALUE AT MINNEAPOLIS.

Local Grade	Weight per bushel lbs.	Value	Minn. Grade	Weight per bushel lbs.	Value
No. 1 N.	57	\$1.58	No. 1 N.	57	\$1.732
No. 2 N.	56	1.54	No. 2 N.	55	1.704
No. 3 N.	54	1.48	No. 3 N.	53	1.626
No. 4 N.	53	1.36	No. 4 N.	48	1.51
No. 4 N.	52	1.30	Sample grade	No limit	1.28
No. 4 N.	49-51	1.24	No grade		1.41
A Feed	47-48	1.14			
B Feed	45-46	.99			
C Feed	43-44	.89			
D Feed	35-42	.79			

Let us use 60,000 pounds as a carload and take the nine grades, assuming that the farmer sold the product at the values here given, and calculate the returns for the same; first, the wheat as received from the farmer; then the wheat as graded in Minneapolis on the track; then the amount received by the elevator company unloaded. If we then take the data furnished from the milling experiments and calculate the market value for the flour, bran and shorts, or mill products, comparing these with the local feed and flour values for the same products as retailed in Fargo, we shall have pretty complete information.

TABLE XIX. NO. 1 NORTHERN: CARLOAD (60,000 POUNDS) BOUGHT FROM FARMER OCT. 14, AT CARD VALUE, \$1.58 PER BUSHEL.

	Grade No. 1°	2°	3°	4° (2)
Dockage, %	3.37	3.96	6.23	6.57
Clean wheat, bus.-lbs.	966-18	960-24	937-42	934-18
Price per bushel	1.58	1.54	1.48	1.30
Value	\$1526.76	\$1479.01	\$1387.73	\$1214.43

If we ship the same wheat to Minneapolis, according to the prices, we should have the following:

TABLE XX. MINNEAPOLIS VALUE OF WHEAT CITED IN TABLE XIX

	Grade No. 1°	2°	3°	4° (2)
Dockage, bus.-lbs.	33-42	39-36	39-36	65-42
Clean wheat, bus.-lbs.	966-18	960-24	937-42	934-18
Price per bushel	\$1.732	\$1.704	\$1.625	\$1.45
Value	\$1673.34	\$1636.35	\$1507.30	\$1354.56
Less freight at 11c per cwt.	\$86.00	\$86.00	\$86.00	\$86.00
Net value on track at Mpls.	\$1607.34	\$1570.35	\$1441.30	\$1288.56
Gain	\$80.59	\$91.34	\$53.57	\$74.13
Value of screenings	\$13.65	\$18.63	\$25.23	\$26.21
Total gain	\$94.24	\$109.97	\$78.80	\$100.34

From the above total gain the farmer would find it necessary to pay his commission and losses.

On the other hand, let us assume that the wheat has gone into the mill, been converted into mill products and sold at Minneapolis wholesale prices, as follows:

TABLE XXI. WHOLESALE PRICE OF MILL PRODUCTS OF WHEAT CITED IN TABLE XIX

	Grade No. 1°	2°	3°	4° (2)
Screenings, lbs.	2022	2376	3738	3942
Screenings value	\$13.65	\$18.63	\$25.23	\$26.61
Straight flour, value	\$1788.66	\$1854.31	\$1631.04	\$1618.68
Bran, value	\$109.42	\$95.58	\$82.04	\$83.88
Shorts, value	\$123.15	\$123.86	\$183.37	\$188.68
Loss in milling				
Total receipts	\$2034.88	\$2092.38	\$1921.68	\$1917.85
Cost of wheat on track	\$1673.34	\$1636.35	\$1507.30	\$1354.56
Gross gain	\$361.54	\$456.03	\$414.38	\$562.29

Now let us assume that the same products have been returned to the retail trade at Fargo and sold at the prevailing prices:

TABLE XXII. RETAIL PRICE AT FARGO OF MILL PRODUCTS OF WHEAT CITED IN TABLE XIX.

	Grade No. 1°	2°	3°	4° (2)
Screenings	\$22.24	\$26.14	\$41.12	\$43.36
Straight flour	\$2244.91	\$2327.30	\$2047.08	\$2031.57
Bran	\$146.21	\$127.72	\$109.62	\$112.08
Shorts	\$145.11	\$145.95	\$216.08	\$222.33
Loss in milling				
Total receipts	\$2558.47	\$2627.11	\$2413.90	\$2409.34
Total gain	\$1031.72	\$1137.10	\$1026.17	\$1194.91

In the same manner let us consider the several other grades.

TABLE XXIII. NO. 4 NORTHERN (3), (60,000 POUNDS), AND THE WHEATS MARKED "FEED" A, B, C, AND D BOUGHT FROM FARMER OCT. 14 AT CARD VALUE, \$1.24 PER BUSHEL.

	Grade No. 4 (3)	Feed A	B	C	D
Dockage, %	6.77	9.24	11.51	8.43	17.34
Clean wheat, bus.-lb.	932-18	907-36	884-54	915-42	826-36
Price per bushel	\$1.24	\$1.14	\$0.99	\$0.89	\$0.79
Value	\$1156.05	\$1034.30	\$876.05	\$814.97	\$653.01

If we ship the same wheat to Minneapolis, according to prices on track, we should have the following:

TABLE XXIV. MINNEAPOLIS VALUE OF WHEAT CITED IN TABLE XXIII.

	Grade No. 4 (3)	Feed A	B	C	D
Dockage, bus.-lbs.	87-42	92-24	115-6	84-18	173-24
Clean wheat, bus.-lbs.	932-18	907-36	884-54	915-42	826-36
Price per bushel	\$1.39	\$1.28	\$1.28	\$1.28	\$1.28
Value	\$1295.73	\$1161.72	\$1132.65	\$1172.09	\$1058.05
Less freight at 11c per cwt.	\$66.00	\$66.00	\$66.00	\$66.00	\$66.00
Net value on track at Mpls.	\$1229.73	\$1195.72	\$1066.65	\$1106.09	\$992.05
Gain	\$73.68	\$71.33	\$190.60	\$291.12	\$339.04
Value of screenings	\$27.42	\$37.42	\$46.62	\$34.14	\$70.23
Total gain	\$101.10	\$108.75	\$237.22	\$325.26	\$409.27

On the other hand, as in previous cases, let us assume that the wheat has gone into the mill, been converted into mill products, and sold at wholesale prices, as follows:

TABLE XXV. WHOLESALE PRICE OF MILL PRODUCTS OF WHEAT CITED IN TABLE XXIII

	Grade No. 4 (3)	Feed A	B	C	D
Screenings, lbs.	4062	5544	6906	5058	10404
Value	\$27.42	\$37.42	\$48.62	\$34.14	\$70.23
Straight flour, value	\$1627.58	\$1537.17	\$1490.96	\$1530.21	\$1327.05
Bran, value	\$103.04	\$100.94	\$109.39	\$110.57	\$109.54
Shorts, value	\$161.68	\$174.49	\$158.71	\$164.85	\$153.33
Loss in milling					
Total value	\$1919.72	\$1850.02	\$1805.68	\$1839.77	\$1660.15
Cost of wheat on track at Minneapolis	\$1295.73	\$1161.72	\$1066.65	\$1106.09	\$1058.05
Gross gain	\$693.99	\$688.30	\$739.03	\$733.68	\$602.10

As in the previous case let us assume that the products have been returned to the retail trade at Fargo and sold at the prices prevailing, or had been purchased back by the farmer who grew the wheat, then for these respective grades we should have:

TABLE XXVI RETAIL PRICE AT FARGO OF MILL PRODUCTS OF WHEAT CITED IN TABLE XXIII

	Grade No. 4 (3)	Feed A	B	C	D
Screenings	\$ 44.68	\$ 60.98	\$ 75.97	\$ 55.64	\$ 114.44
Flour	2042.74	1929.26	1871.27	1920.54	1665.55
Bran	137.69	134.88	146.17	147.75	146.37
Shorts	190.51	205.61	187.02	194.25	180.67
Loss in milling					
Total receipts	\$2415.62	\$2330.73	\$2280.43	\$2318.18	\$2107.03
Increased cost	\$1259.57	\$1295.34	\$1404.38	\$1493.21	\$1454.02

SUMMARIZED STATEMENT:

Let us summarize more fully the data presented for the carload lots by taking the totals as received for the products at market value and show how much it has cost the farmer who brought in the carload of wheat at Fargo and purchased, at market prices, the mill products therefrom, as well as the intervening prices that prevailed at the terminal and as the wholesale prices for the mill products. The results will be as follows:

TABLE XXVII. A CARLOAD OF WHEAT FROM FARMER TO CONSUMER

Grade	Price paid farmer	Minnea- polis price on track	Mill Products	
			As wholesaled	As retailed at Fargo
No. 1 Northern	\$1520.75	\$1607.34	\$2034.88	\$2558.47
No. 2 Northern	1479.01	1570.35	2092.38	2627.11
No. 3 Northern	1387.73	1441.30	1921.68	2413.90
No. 4 Northern (2)	1214.43	1288.56	1917.85	2409.34
No. 4 Northern (3)	1156.05	1229.73	1919.72	2415.62
A Feed	1034.39	1195.72	1850.02	2330.73
B Feed	876.05	1066.65	1805.68	2268.43
C Feed	814.97	1106.09	1839.77	2318.18
D Feed	653.01	992.06	1660.15	2107.03

In the above we have attempted only to follow through a concrete example of a carload of wheat so as to show more specifically what each grade would be valued at according to the system

of grading and marketing prevailing in the several localities. In other words then, the farmer who sold one carload of wheat, 60,000 pounds, at Fargo and purchased back the mill products from the same, as returned from Minneapolis, pays for the transaction above the price which he received for his wheat for the several grades, as follows:

TABLE XXVIII. INCREASED COST OF MILL PRODUCTS OVER PRICE FOR WHEAT

No. 1 Northern	\$1031.72
No. 2 Northern	1148.10
No. 3 Northern	1026.17
No. 4 Northern (2)	1195.41
No. 4 Northern (3)	1259.57
A Feed	1295.34
B Feed	1404.38
C Feed	1493.21
D Feed	1454.02

In other words, on an investment for low grade wheat which costs, for a carload, less than one-half of that for a high grade wheat, there was a total income very much greater than for the best wheat on the market. For example, in grade D Feed, the carload cost \$653.01 as compared with \$1526.75 for grade No. 1 Northern; while the increase in selling price over that of the cost price for Feed A wheat would be \$1454.02 and only \$1031.72 on No. 1 Northern. This would seem to lead back to the original question as given in our first bulletin,—“Is the Present System of Grading Wheat Equitable?”

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North Dakota Agricultural Experiment Station

The Capacity of Wheat and Mill Products for Moisture

By W. L. Stockham

Bulletin No. 120

Agricultural College, North Dakota

January, 1917

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CONTENTS.

	Page.
SOIL SURVEY OF DICKEY COUNTY, NORTH DAKOTA. By T. M. BUSHNELL, in charge, E. H. SMIES, and W. I. WATKINS, of the U. S. DEPARTMENT OF AGRICULTURE, and A. O. ANDERSON, MELVIN THOMAS, MURRAY E. STEBBINS, R. C. DONEGHUE, and J. W. INCE, of the NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION.....	5
Description of the area.....	5
Climate.....	7
Agriculture.....	10
Soils.....	19
Lamoure very fine sandy loam.....	21
Lamoure silt loam.....	21
Lamoure silty clay loam.....	22
Lamoure silty clay.....	22
Lamoure clay.....	23
Bearden fine sand.....	23
Bearden loamy fine sand.....	26
Bearden fine sandy loam.....	26
Bearden very fine sandy loam.....	27
Bearden silt loam.....	28
Fargo silty clay.....	28
Sioux loam.....	30
Sioux gravelly loam.....	30
Sioux sandy loam.....	32
Sioux fine sandy loam.....	32
Sioux silt loam.....	33
Rogers silty clay.....	33
Maple clay loam.....	34
Barnes very fine sandy loam.....	35
Barnes loam.....	36
Barnes silt loam.....	39
Barnes silty clay loam.....	43
Williams fine sandy loam.....	44
Williams gravelly loam.....	45
Williams loam.....	46
Edgeley loam.....	47
Valentine fine sand.....	50
Valentine fine sandy loam.....	52
Rough broken land.....	53
Chemical composition of soils.....	54
Summary.....	55

ILLUSTRATIONS.

PLATES.

	Page
PLATE I. Fig. 1.—View of Lake Dakota region. Fig. 2.—Sioux gravelly loam, colluvial phase, with Rough broken land in background.....	16
II. Fig. 1.—Cut in Williams gravelly loam. Fig. 2.—“Gulch” in Rough broken land northwest of Forbes.....	18

FIGURE.

FIG. 1. Sketch map showing location of the Dickey County area, North Dakota.	5
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MAP.

Soil map, Dickey County sheet, North Dakota.

SOIL SURVEY OF DICKEY COUNTY NORTH DAKOTA.

By T. M. BUSHNELL, In Charge, E. H. SMIES and W. I. WATKINS, of the U. S. Department of Agriculture, and A. C. ANDERSON, MELVIN THOMAS, MURRAY E. STEBBINS, R. C. DONEGHUE, and J. W. INCE, of the North Dakota Agricultural Experiment Station.

DESCRIPTION OF THE AREA.

Dickey County, N. Dak., lies on the eastern part of the southern boundary of the State. It is rectangular in shape, and is bounded on the north mainly by Lamoure County, on the east by Sargent County, on the south by the South Dakota State line, and on the west by McIntosh County. The county is 48 miles long and 24 miles wide, and has an area of 1,142 square miles, or 730,880 acres.

Dickey County occupies portions of two plains, known, respectively, as the Prairie Plains and the Missouri Plateau. The first of these is the lower, having a range in elevation from about 1,300 to 1,600 feet above sea level. Although there is a gradual descent from the west, the area slopes also toward the south, as is indicated by the stream courses. The greater part of the surface is characterized by an undulating to gently rolling topography.

The local topography is uniform over the country, being typically that of a ground moraine of faint expression, with extremely faint dissection. The valleys, excepting that of the James River, are rarely more than 25 feet deep or one-fourth mile in width. The James River has a valley about 125 feet deep and varying in width from about 1 mile to more than 8 miles in the expansion of the valley south of Oakes, known as the bed of Lake Dakota. The latter is a broad plain of constructional water-laid topography lying about 20 feet above the level of the James River. (See Pl. I, fig. 1.)

Beginning on the southwestern side of the big bend of the James River and following a course slightly west of south is what appears to be the remains of an old spillway of the James River. This is about 3 miles wide at the north end, but narrows after passing a point just west of Clement. It practically disappears in Kent Township, but there are indications that the drainage divided at this point, one branch going south just west of Guelph and the other passing

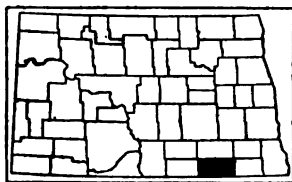


FIG. 1.—Sketch map showing location of the Dickey County area; North Dakota.

east of Silverleaf on its course toward the Maple River Valley. This strip of land is characterized by a large number of poorly drained areas, which occur in chains, and by rough topography in contrast with the surrounding country.

The second main physiographic division of the county, the Missouri Plateau, is a plain like the Prairie Plains, but it has an elevation of about 2,000 feet above sea level. In this region there are two types of minor surface relief; one consists of the comparatively narrow, eroded edge of the plateau and the other of the surface of the plateau covered by sharply rolling morainic hills with small inclosed basins of restricted drainage. This plateau is known as the Missouri Coteaus, and probably represents a preglacial plateau modified by the deposition of glacial material on its surface. The overburden of glacial drift is a part of the Altamont moraine. The eastern bounding escarpment passes across the State in a northwest-southeast direction, but in this county its front has a north-south direction. Its width in the county varies from about 9 miles in the northern part to about 6 miles in the southern part. At the northern line of the county the ascent from the lower plain is gradual, but toward the south the slope is much steeper and the ascent of 200 feet or more takes place in less than a mile. On the plateau proper regional drainage has not been established and the original constructional surface has been little modified by erosion.

The regional drainage of the county, where it has been established, is effected by a large number of almost parallel streams which have a general trend slightly east of south. The larger streams, the James and Maple Rivers, make their eastward turn through sharp berds in the northern part of the county. The main drainage ways that rise in the county follow a course almost due south to the county line. The James River is the most important stream in the county, and all the streams after they leave the county find their way, through the James, into the Missouri.

In the old Lake Dakota basin local drainage has not been established, but the rainfall sinks rapidly into the sandy soil. In low areas of heavy soil where seepage accumulates poorly drained areas, lakes, and marshes occur. Local drainage is poorly established along the eastern edge of the upland prairie. Toward the moraine, as the slope is more pronounced, drainage ways are more generally developed, but there are still many extensive areas without streams. In most places the run-off is carried into depressions by shallow swales. Innumerable small areas of restricted drainage are found over the entire region, except on the slopes bordering the moraine.

The population consists mainly of immigrants and the descendants of immigrants who came into the county principally from Wisconsin, Iowa, Illinois, and other Central States. According to the 1910 census, 77.6 per cent of the population is native born. The

greater part of the foreign-born population is from Russia, Norway, Canada, and Finland. The total population of the county is reported in the census of 1910 as 9,839, as compared with a total of 6,061 reported in 1900. The entire population, as reported in 1910, is given as rural, and averages 8.6 per square mile.

The two principal towns in Dickey County are Ellendale, which is the county seat and has a population of about 1,400, and Oakes, with a population of about 1,500, according to the 1910 census. These are progressive cities with modern improvements. Fullerton, Forbes, Monango, Ludden, Merricourt, and Guelph are small towns with populations ranging from about 100 to 300.

Dickey County includes somewhat over 130 miles of railroad and 20 shipping points. One-half the farms of the county are within 3 miles of some elevator or loading platform and four-fifths within 6 miles. A large area in the vicinity of Wirth is 10 to 18 miles distant from the nearest railroad. The railroads afford direct transportation to Minneapolis and St. Paul, and the markets in these cities determine the values of farm products in Dickey County to a large extent.

A strip along every section line is legally reserved for a public road, but the roads are interrupted in a few places by natural obstacles, especially along the James and Maple Rivers and in the rough country in the western part of the county. Most of the roads are mere wagon tracks worn down through the prairie sod to depths of 4 to 12 inches, but the main roads to the towns usually are graded. Much interest is being taken in the establishment of good roads, and the old trails are being fenced across, while scrapers and grading machines are being used for building fills through depressions and digging road ditches. Where available, gravel is used as a surfacing material. The James River is bridged at seven well-distributed points in Dickey County, while the roads on twenty or more section lines stop near its banks.

Two sections in each township are reserved for school purposes, and the country schools are in good condition and well conducted for a new, thinly settled country. Telephone lines and the rural delivery of mail reach all parts of the county.

CLIMATE.

The climate of Dickey County is subhumid, with comparatively long winters and short summers. Thawing weather usually begins about the middle of March, and field work starts by April 10. From this time until May 10 the weather is usually quite cool and growth is comparatively slow. After this time the higher temperature and long bright days result in a much more rapid growth, which continues until the small grains mature, except when growth is checked by occasional periods of drought. There are very few hot days and the nights are cool.

As a rule, the fall season is comparatively dry and there are many days of fair weather. The ground seldom freezes before the middle of November. During short periods of extremely cold weather the thermometer may occasionally register as low as 40° below zero. The dry air makes the cold less penetrating than in the more humid regions. These periods are less disagreeable than when "blizzards" occur, and moderately low temperatures are attended by high winds.

Weather Bureau observations at Berlin for 19 years show the frost-free period to be 102 days. The average date of the last killing frost in the spring has been June 2, and the first in the fall September 12. The latest frost in the spring has been June 21, and the earliest in the fall August 31. At the substation at Edgeley 15 years' records, 1901-1914, show the frost-free period to be 129 days. The average date of the last killing frost in spring is May 14 and the first in fall September 20. At Fullerton, Weather Bureau records show the frost-free period to be 122 days, the average date of the last spring frost being May 17 and the first fall frost September 16. The latest in the spring occurred on June 7 and the earliest in the fall on August 12. The average frost-free period for the three points is 117 days.

Normal monthly, seasonal, and annual temperature and precipitation at Fullerton.

Month.	Temperature.			Precipitation.		
	Mean.	Absolute maximum.	Absolute minimum.	Mean.	Total amount for the driest year.	Total amount for the wettest year.
	^{° F.}	^{° F.}	^{° F.}	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
December.....	14.3	53	-33	0.95	0.46	1.89
January.....	10.4	60	-40	0.63	0.02	1.17
February.....	9.0	58	-38	0.65	0.40	0.22
Winter.....	11.2	60	-40	2.24	0.87	3.25
March.....	24.0	72	-27	1.57	0.67	0.89
April.....	42.1	88	-15	1.83	1.35	2.82
May.....	53.2	95	13	3.35	2.24	8.05
Spring.....	39.8	95	-27	6.81	4.26	11.79
June.....	62.3	100	26	3.23	1.56	4.43
July.....	67.6	105	32	3.13	2.68	5.39
August.....	66.3	102	31	2.92	2.45	2.30
Summer.....	65.4	105	26	9.28	6.69	12.03
September.....	56.5	99	16	2.07	0.64	2.89
October.....	44.4	86	10	1.52	1.74	1.65
November.....	29.3	72	-27	0.72	0.18	2.28
Fall.....	43.4	99	-27	4.31	2.56	6.73
Year.....	49.5	105	-40	22.64	14.38	33.57

Records of the rainfall during the seven months from April to October are available for the five-year period 1910-1914. These are given in the following table:

Summary of rainfall data at Oakes Demonstration Farm.¹

Month.	1910	1911	1912	1913	1914
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
April.....	0.00	0.98	2.72	0.79	3.62
May.....	.56	4.12	2.91	2.40	1.15
June.....	1.56	2.18	2.17	2.22	6.97
July.....	.94	1.56	5.73	2.20	3.07
August.....	2.28	2.78	2.68	3.14	.76
September.....	3.23	2.94	2.48	.34	1.75
October.....	.40	.85	.12	3.56	.64
Total.....	9.02	15.41	19.31	15.35	17.96

¹ Compiled from published records in Annual Reports of the Superintendent of Demonstration Farms 1910-1914.

A record of evaporation from a free water surface during the growing season have been kept for several years at the Edgeley substation. This together with precipitation for the same period is summarized in the following table:

Precipitation and evaporation for the growing season, 1907-1912.¹

MONTHLY PRECIPITATION.

Month.	1907	1908	1909	1910	1911	1912
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
May.....	1.89	3.55	4.01	0.36	2.31	3.26
June.....	1.73	3.26	2.60	1.57	1.19	3.23
July.....	2.77	1.19	3.04	.60	1.76	5.70
Total.....	6.39	8.00	9.65	2.53	5.26	12.77

MONTHLY EVAPORATION.

May.....	3.41	4.08	4.40	5.08	5.47	4.40
June.....	5.46	5.21	4.19	6.72	5.43	3.08
July.....	5.98	7.04	5.63	3.19	7.56	5.70
Total.....	14.85	16.33	14.22	20.99	18.46	13.18
Evaporation times rainfall.....	2.32	2.04	1.44	8.14	3.51	1.08

¹ N. D. Agr. Expt. Sta., Tenth Annual Report of the Edgeley Substation 1912, p. 11.

Seven years' records during the months of April to September show the average total evaporation from a free water surface to be equivalent to 30.42 inches of rainfall.¹

¹ N. D. Agr. Expt. Sta. Bul. 116, p. 169.

Over one-half the rainfall comes in May, June, July, and August. This is fairly well distributed through these months. On the better soils that are well tilled and in a high state of fertility the average rainfall during these months alone is sufficient to produce a fair crop, if it could all be utilized. The evaporation from a free-water surface is quite high and indicates that moisture can be lost very rapidly from a moist soil.

AGRICULTURE.

The lands of the county were surveyed and opened for entry in the early eighties, and considerable land was taken up in the eastern part of the county by homesteading, preemption, and tree claims. In 1890 the census figures show that 337,844 acres, or about 45 per cent of the county, was in farms. Of this, 178,460 acres, or about 53 per cent of the land in farms, was improved. In 1900 there were 470,910 acres in farms in the county, or 63 per cent of the land area. The percentage of improved land in farms was practically the same as in 1890. In 1910 there was 594,630 acres, or about 80 per cent of the land area, in farms, and about 69 per cent of the land in farms was improved.

The average value of land in farms advanced from \$5.40 to \$33.45 per acre in the decade from 1900 to 1910. During this decade the value of farm buildings advanced from 94 cents to \$3.06 per acre of land in farms, the investment in farm machinery from 45 cents to \$1.66 per acre, and the investment in live stock from \$2.07 to \$3.86 per acre.

While there has been a great increase in the land area in farms during the 20-year period from 1890 to 1910, the number of farms has not shown a marked increase. In 1890 there were 997 farms in the county, and the average size was 339 acres. In 1900 the number had decreased to 933 and the average size had increased to 504 acres. In 1910 there were 1,089 farms, the average size being 546 acres. Of this number 792 were operated by owners. These 792 farms constituted 73 per cent of the land in farms and averaged 610 acres per farm. Seventy-eight per cent of the land in farms was improved. This is 9 per cent more than the average for the country. The greater part of the land not operated by owners is leased under the share-tenant system.

Wheat has always been the principal crop grown in Dickey County, although there has been a gradual decrease in the percentage of improved land in farms that has been seeded to this crop. In 1890 the wheat acreage was 52 per cent of the improved land in farms, while in 1900 it was but 41 per cent and in 1910 it was 38 per cent. Oats have been grown primarily for horse feed, and the relative acreage has not changed materially. Barley supplemented wheat as a sale

crop to some extent on some farms, as is shown by the fact that the percentage of the improved land in farms devoted to this crop increased 7 per cent during the decade from 1900 to 1910. While barley has taken the place of wheat to some extent on old land, flax has supplanted it to a considerable extent on newly broken prairie sod. The percentage of the improved land devoted to flax increased approximately 5 per cent during the 20-year period from 1890 to 1910. This increase was no doubt due to the breaking of new prairie sod, because flax is usually grown when the sod is broken up. Flax is not very generally grown on land that has been under cultivation for any length of time.

In 1899 there were 52,384 acres of wild hay cut in the county, and in 1909 there were 58,212 acres. Prior to the time the land was put under cultivation it was used for ranching, and considerable wild hay was cut for feeding the live stock during the winter. The census figures show that only 125 acres were devoted to the production of forage crops in 1900, but in 1910 there were 3,327 acres of tame and cultivated grasses. Most of this was timothy and millet.

Rye and broom-corn millet are grown to some extent in the county, and potatoes and other vegetables are grown for home use.

The census figures show that there were 3,170 plum trees in the county in 1909. Some strawberries, raspberries, currants, and gooseberries are also grown.

Before the land was brought under cultivation considerable live stock was grazed in the county under the ranching system. The cultivation of the land broke up the ranches, and much of the live stock was sold. Many of the farmers are beginning to stock their farms, so that eventually there will be considerable live stock raised in the county. The changes that have taken place in the live-stock industry are illustrated in the following table:

Number of acres in farms for each head of live stock, 1890-1910.

Animal.	1890	1900	1910
	Acres.	Acres.	Acres.
Horses.....	72	61	47
Milch cows.....	116	116	114
Other cattle.....	50	26	50
Sheep.....	75	26	435
Hogs.....	110	117	68

The ratio of horses to land in farms has steadily increased during the 20-year period. This is probably due to the fact that a greater proportion of the horses are now used on the farms and fewer on ranches, where they were formerly used as saddle horses. The ratio

between milch cows and the land in farms has not changed, showing that during this period the dairy products were largely consumed on the farms. The ratio of other cattle has undergone some marked changes. There were over twice as many acres of land in farms per head in 1890 as in 1900. Probably most of the cattle were on ranches which were not included in the land in farms, so that this would not necessarily represent an increase in the number of cattle on the farms. This is borne out by the fact that there were only one-half as many acres of land in farms for each head in 1900 as in 1910, while there was an increase in the acreage under cultivation. The same conditions apply to sheep, except that the differences were more marked, showing that the sheep sold from the ranches have not been replaced as generally as has been the case with cattle. The number of acres in farms for each hog did not change materially during the first decade, but there was a decrease of 55 acres per hog from 1900 to 1910. Hog raising is becoming more general and some of the corn grown is hogged off in the fall. Beef cattle are raised on some of the farms in the county. They consume much of the roughage that would otherwise be unmarketable, and where they have access to straw stacks they convert large amounts of straw into manure so that it can be returned to the soil to build up the organic content.

The agriculture of the region is still comparatively new, and little attention has been given to the adaptation of crops to soils. The same crops have been grown on all types. The problem of checking the drifting of certain soil types by the wind has led some farmers to grow crops that make it possible to utilize these soils to better advantage. The necessity of ridding wheat land of weeds has also caused some diversification of crops. While some of the land has been cultivated about 30 years, there is much of it that has been under cultivation a much shorter time. Although the live-stock industry has undergone some changes, this has not been due to change in the method of farming, but rather to a change from ranching to farming. Small grains have been grown almost exclusively until the last few years. Much of the land has become infested with wild oats and some other weeds under this system. The acreage of corn has increased quite rapidly and quite a number of farmers are planting large acreages. Good yields are obtained and the crop is proving to be one of the most profitable in the county. Many farmers are growing alfalfa in a small way, and it is one of the most promising hay crops. Considerable broom-corn millet is grown for seed.

VARIETIES OF GRAIN.

Variety trials at Edgeley, in Lamoure County, during an 11-year period show that the durum wheats yielded from three to five bushels

more than the Fife or Blue-stem varieties. Velvet Chaff or bearded spring wheats have not yielded quite as much as the Fifes and Blue-stems, and Ghirka spring wheat has produced about the same yield as these varieties.

The early oats, such as the Sixty Day and Kherson, yield more in dry years than the medium and late ripening strains. The late oats, for example the White Russian, are more rust resistant than early or medium maturing strains. The medium-maturing varieties, such as the Siberian White, outrank the other sorts in point of yield, for an average during a term of years. The Kherson and Sixty Day oats yielded from 20 to 25 bushels per acre in the dry season of 1910 and 1911, where most of the other sorts were a failure. From the data accumulated, it would seem advisable for the farmers to sow about half their acreage intended for oats to one of the early strains and the balance to a medium-ripening sort. On an average the early oats ripen about 15 days before the other varieties are ready to harvest. As very hot, dry weather usually occurs after the middle of July, which is the ripening period of the early varieties, very little damage is done by drought.¹

The 6-rowed barleys have yielded slightly more than the 2-rowed varieties.

The suitability of a variety of corn for the county depends largely upon the region in which the seed has been produced. Rustler White Dent and Minnesota No. 13 Yellow Dent can be grown quite successfully in the region, if seed from a strain that has been growing in the region for several years is planted. Early strains of these varieties have been produced by growers in this and adjoining counties who have been selecting for earliness for several years. The growing season for corn is too short for strains of these varieties grown in the States farther south. Mercer Flint grown from northern-grown seed makes a good silage corn. Early selected improved strains of Northwestern Dent are well suited to the region. Gehu Flint and Dakota White Flint can be grown successfully and are well suited to hogging off.

TILLAGE METHODS.

Experiments have been in progress for several years at the Edgeley substation to determine the best methods of seed-bed preparation. Though these results apply more particularly to the management of the Edgeley loam they have a general bearing on tillage practices of many of the soils of the county. The results also indicate the benefits of tillage practices in general, as compared with other phases of soil management.

Experiments have been in progress since 1909 to determine the effects of different times of plowing on the yield of wheat in a system of continuous cropping. The average yield has been slightly higher on spring-plowed than on fall-plowed land. Early-fall plow-

¹ N. D. Agr. Expt. Sta., Tenth Annual Report of Edgeley Substation, p. 30.

ing (about Sept. 1) is best. Under farm conditions early-fall plowing would probably prove more profitable than spring plowing, because when a considerable acreage of grain is seeded some of it must necessarily be seeded rather late, if the sowing is delayed by plowing in the spring. The decrease in the yield due to this later seeding would usually be enough to offset any better soil conditions that might be brought about by spring plowing. If the acreage devoted to grain is not too great it would probably be better to plow in the spring than late in the fall.

During this same period an investigation has been made to determine the relative yields on land plowed 5 inches deep and land plowed 8 inches deep. This work has been done on both fall and spring plowed land. The yield on fall-plowed land has been practically the same for both depths, while the difference in the spring has been within the limits of experimental error. These results show that there is little advantage in plowing over 5 or 6 inches deep in a system of continuous grain growing under the soil and climatic conditions of the region.

Plowing has a loosening effect on the soil, and on some of the coarser textured soils that are naturally loose in structure it is possible that deep and frequent plowing makes them too loose for the best growth of crops. This is borne out by results of an experiment, in which the land was cropped continuously to wheat as in the foregoing plowing experiments. One set of plots was plowed in the fall and seeded the following spring. No tillage was given in the fall after harvest, but the following spring the stubble was disked and seeded to wheat. On the other set of plots the ground was plowed for wheat in the spring and seeded. The stubble was disked that fall and seeded the following spring. In this way the land was plowed but once in two years.

As an average for the two systems of treatment, the yields were 1.55 bushels per acre higher in years in which the land was plowed, but the only treatment that produced a greater average yield when the land was plowed every year was the spring plowing, and this yielded only about one bushel more. While a system of alternate plowing and disking of this kind might not be advisable as a permanent system, because of the fact that continuous cropping to grain is becoming impractical, the data show that a cropping system devised so that plowing will not need to be done every year would result in better yields. In a region of relatively low rainfall the soil settles slowly and when stirred deep too frequently the best conditions for the movement of soil moisture and the growth of crop roots do not exist. The cultivation of corn grown in the rotation packs the soil and produces a soil structure that, while loose enough to favor bac-

terial activities, is uniform and compact enough to permit the movement of soil moisture and plant food for crop nourishment.

In order to overcome the loosening effect of deep and frequent plowing in the subhumid region it has been suggested that the soil be packed after plowing. In order to determine the effectiveness of subsurface packing an experiment was conducted in which 8-inch fall and spring plowing was packed. A comparison of the yields of these plots with plots similarly treated but not packed showed that packing was ineffective in bringing about a soil structure that is favorable for the growth of wheat. A more compact structure is needed, but the packer does not seem to compact the soil uniformly and thoroughly enough to improve its condition for the growth of wheat in a system of continuous cropping.

During the 4-year period, 1912-1915, subsoiling experiments have been in progress at the Edgeley substation. Hard wheat, durum wheat, barley, oats, and corn have been grown in these trials.

The land was subsoiled to a depth of 7 inches below the 6-inch plowing, thereby stirring the soil to a depth of 13 inches. The subsoiling and packing have been done but once during the 4-year period, for the 1912 crop, except where barley was grown, which was subsoiled and packed in 1913. All plots have been plowed 6 inches deep each year. There has been no appreciable increase in yield due to the subsoiling or packing for hard wheat or durum, except in 1912, when there was an increase of 4 bushels. This was offset by the lower yields in the subsoiled plot in 1913 and 1915, so that the operation would not be profitable.

The three years' work with barley shows a slight decrease for subsoiling, both when packed and when not packed. The subsoiling produced a slight increase in the yield of oats and corn as an average for the 4-year period, but packing reduced the yield below that of the 6-inch plowing in case of both crops. The value of the increased yield of oats on the subsoiled plots in 1912, less the decrease in the three succeeding years, was \$2.34 per acre and that of the corn fodder \$2.06, when oats are figured at the average farm price for the 10-year period 1905-1914 and corn fodder at two-thirds the average price of hay during this period.

During a period of nine years at Edgeley 12 plots of corn ground have been disked for wheat and 3 have been plowed. As an average of all these for the entire period the wheat on the plowed plots has yielded but one-tenth bushel per acre more than that on the disked plots. Oats on corn ground plowed yielded the same as on disked corn ground.¹

¹ N. D. Agr. Expt. Sta. Bul. 110, pp. 183, 194, 199.

SUMMER TILLAGE

In comparing the yields of crops on land that grows a crop every year with those on land that is fallowed and tilled during the summer to keep down weeds, it is found that the summer-tilled land produced an average yield of 1.6 bushels per acre, or about 12 per cent, more wheat than land cropped continuously during a 9-year period of investigation. Oats yielded 15.7 bushels per acre, or 58 per cent more, and barley 3 bushels per acre, or 17 per cent, more, on summer-tilled land. The yield of corn was slightly lower on summer fallow than on land that grew corn every year.

The results of the foregoing experiments show that under these conditions the yield of small grain can not be materially increased by plowing deeper than 5 or 6 inches, by subsoiling or by packing in a system of continuous cropping. They further indicate that when land is plowed every year the soil is loosened too much, especially in the case of the coarse-textured soils under the climatic conditions of the region. This loosening can not be corrected by the use of the packer enough to make subsurface packing profitable on the Edgeley loam. When the packer is used the structure of the soil is not as uniformly compact as when it is allowed to settle for more than one year. The cultivation of corn works the soil into a uniformly compact structure gradually and at the same time eliminates weeds and leaves the soil in good physical condition for small grain, so that plowing is unnecessary for the succeeding crop of small grain. Two crops can be grown with one plowing in this way and the soil will be in good tilth for both. For most farm conditions early-fall plowing of grain stubble would prove best for growing a second crop of small grain. Small grain grown on spring plowing will yield better than on late-fall plowing, provided the grain can be seeded equally early in the spring.

The practice of summer tillage or the clean culture of bare fallow every other year has not been found profitable. It may be advisable to give the land summer tillage once in 4 or 5 years as a means of cleaning the land of weeds, but the growing of corn or potatoes in a rotation would prove more profitable.

The tillage methods that should be followed vary somewhat with the soil type. The purpose of tillage practices on all soil types is to eliminate weeds, to improve soil structure, to facilitate the absorption of the rainfall by the soil and the movement of the moisture in the soil, so that crops are supplied with food at critical stages in their growth, and to promote the action of soil bacteria. These effects are produced in different soils by different systems of soil management. A clay soil has a tendency to become refractory and offers considerable resistance to the growth of crop roots unless it



FIG. 1.—LAKE DAKOTA REGION, LOOKING WESTWARD FROM TOP OF A SAND DUNE.
Dune is just inside of Sargent County.



FIG. 2.—SIOUX GRAVELLY LOAM, COLLUVIAL PHASE, WITH ROUGH BROKEN LAND IN BACKGROUND.

A deep draw occurs between this flat and the hills.



FIG. 1.—CUT IN WILLIAMS GRAVELLY LOAM.

Here there is some stratification, and the gravel occurs along the slope of a long morainal hill.



FIG. 2.—“GULCH” IN ROUGH BROKEN LAND NORTHWEST OF FORBES.

is worked into a granular condition. This is accomplished by plowing, disking, and harrowing when the soil contains the proper amount of moisture. Obviously, different systems of tillage should be followed in the management of a sandy soil, where the principal object of tillage, from the standpoint of modification of soil structure, is to incorporate organic matter and produce a uniformly compact structure, so that as much moisture as possible will be retained.

CROP ROTATION.

While proper tillage is important from the standpoint of economy in the production of a maximum crop, the best results can not be obtained unless crops are grown in a rotation.

During a period of eight years the yields of wheat at Edgeley have been practically the same on corn ground as on summer tillage, the yields of barley have been 3.4 bushels less on summer tillage, and the yields of oats have been 5.2 more on summer tillage than on corn ground.¹ The average value of the corn fodder produced during that period, calculated from the average yield of 22 plots at two-thirds of the average price of hay for the 10-year period 1905-1914, was \$7.10 per acre.

The best yields of small grain have been obtained on corn ground. The growing of corn in the rotation has increased the yield of succeeding crops of barley and wheat more than it has the yield of oats. On account of its higher price wheat will usually produce a more profitable increase than barley. For this reason wheat should usually take precedence over barley on corn ground. If the price of barley should be the same as that of wheat or even slightly lower, the former crop would be preferable because the increase in the yield of barley due to placing corn in the rotation was 37 per cent of the crop grown in a system of continuous cropping, while the increase for wheat was but 33 per cent. Either wheat or barley can be grown to better advantage than oats on corn ground because of the fact that the increase in the yield of oats due to the placing of corn in the rotation was but 22 per cent of the yield where oats were grown continuously. The yield of oats following wheat and barley was almost equal to that on corn ground. Results at some of the other substations indicate that the increase in oat yields following corn grown on some soil types is greater than the increase obtained at Edgeley. All figures show, however, that oats do better following a small grain than does either wheat or barley.

The yields of small grains immediately following alfalfa and brome grass have been less than on land that had grown small grain

¹ N. D. Agr. Expt. Sta. Bul. 110, p. 190.

the preceding year. Corn and flax are usually better crops than wheat, oats or barley to be grown on sod. Brome grass and alfalfa take large amounts of water from the soil and unless there is considerable rainfall during the growing season succeeding crops frequently suffer from drought.

On the Fargo clay of the experiment station farm at Fargo the growing of timothy in the rotation has increased the yield of wheat 35 per cent. There was practically no increase the first year after timothy, but in later years there was a marked increase.

Sweet clover seems to be the most promising legume crop for the rotation in this region. Alfalfa can be worked into the rotation gradually. Land on which alfalfa has been grown for several years can be broken up and put in the rotation, and one of the fields that has been in the regular cropping system seeded to alfalfa. In this way alfalfa will have been grown on all the fields of the farm in the course of several years. While it will take a long time to get the beneficial effects of alfalfa on all parts of the farm, the manure produced when the alfalfa is fed can be applied to other fields so that the organic content of the entire farm may be maintained.

Weeds cause a considerable decrease in the yield of crops grown in the county and if they are to be controlled some cultivated crop like corn or potatoes must be grown. Seeding the land to grass or alfalfa will also help to eliminate many weeds. The greater economy of moisture and plant food when cultivated crops are grown systematically in the rotation will result in an additional increase in yield.

As an average of six years' results at Edgeley the application of nine loads of manure per acre to the fallow in a 4-year cropping system, consisting of fallow one year, wheat one year, corn one year, and oats one year, resulted in an increase of 3.6 bushels in the yield of wheat, 760 pounds of corn fodder, and 5.9 bushels of oats. In a rotation of fallow one year, oats one year, corn one year, and wheat one year the increase was 3.4 bushels of oats, 720 pounds of corn fodder, and 0.3 bushel of wheat, showing that greater returns are obtained from both wheat and oats when the former is grown the year following manuring.¹

In a 4-year rotation arranged in the following order: Green-manure crop plowed under one year, small grain one year, corn one year, and small grain one year, no beneficial effects have been obtained from green manure in eight years' experiment at Edgeley. Rye, peas, and sweet clover were used as green-manure crops.² Probably better results would have been obtained had corn followed the green-manure crop. The cultivation of the corn crop would improve the structure of the soil for the production of small grain and facilitate

¹ N. D. Agr. Expt. Sta. Bul. 110, pp. 188, 189.

² *Ibid.*, pp. 186, 187.

decay. All things considered, it would not pay to give up the land one year for green manuring under present conditions. Large amounts of organic matter can be added to the soil in this way and eventually returns could be expected, but a smaller amount of organic matter can be added if a crop like sweet clover is grown in the rotation, the first crop being cut for hay. The second growth can be plowed under, but considerable organic matter is added even if this is cut. Small amounts of organic matter added in this way do not involve the loss of the use of the land, and the immediate results are sometimes better than if large amounts are plowed under.

SOILS.

The soils of the county are derived from glacial drift, either weathered in the position in which it was left by the ice or transported and redeposited in glacial lakes as terraces along glacial streams, or as recent alluvium. The drift of this region was deposited by the Dakota lobe of the great continental ice sheet during the Wisconsin stage of ice invasion, and ranges from a thin veneer to beds 80 or 90 feet in thickness. The composition of the material varies widely, the drift being made up of granite, limestone, shale, and sandstone of many formations and in various stages of attrition.

The upland drift has not been greatly modified by erosion, and the variations in the soil are due to differences in the original material or to weathering and the accumulation of organic matter. In the redeposited soils of the level lake beds and terraces, owing to the heavier growth of vegetation, larger quantities of organic matter have accumulated, so that the color of the material is relatively dark.

The soils of the glacial drift are classed with three soil series, the Barnes, Williams, and Edgeley. The Barnes series is characterized by dark-brown to black surface soils and light-brown to yellowish-brown, greenish-brown or grayish-brown, highly calcareous subsoils. The topography is level to rolling, and the greater part of the series constitutes good farming land. The Williams series is mapped on the Missouri Plateau, and is distinguished from the Barnes series by its slightly thinner black soil layer and by lighter colored subsoils. In plowed fields the soil color is often browner than that of the Barnes. The soil is productive, but the topography is often unfavorable for cultivation. The Edgeley series resembles the Barnes in color, but is underlain by a dark-colored shale rock within 5 feet of the surface, and contains considerable quantities of fragmental shale. This soil is comparatively unproductive.

The glacial-lake and river-terrace soils are classed with six soil series, the Sioux, Fargo, Rogers, Maple, Bearden, and Valentine.

The Sioux series has dark-brown to black soils and light-brown or yellowish-brown, calcareous subsoils, and is droughty because of a porous gravel substratum within a few feet of the surface. The Fargo series has a dark-brown to black soil and a gray to mottled gray and yellow, calcareous subsoil. The drainage is poor. The Rogers series is poorly drained and has a dark-colored soil with a light-gray or drab, calcareous subsoil, though there are large areas in which the soil is lighter colored, owing to the presence of alkali. This series usually is closely associated with the Edgeley, and is unproductive. The Maple series has a dark-gray or bluish-gray soil and a bluish-gray or gray, calcareous subsoil. It is underlain by gravel, but is poorly drained, occurring in depressions or old drainage channels. The Bearden series is mapped on high terraces along the James River Valley. The soils are dark brown to black and the subsoils yellowish brown and calcareous. The series is not droughty, and the material has a close, uniform structure something like loess. Where sand has been reworked and heaped up by wind action the resulting soils are very loose, incoherent, and droughty, and are classed with the Valentine series.

The first bottoms along the streams in Dickey County are seldom overflowed, because of the small volume of water in the drainage ways. The bottoms are classed with the Lamoure series. The surface soils are black to dark brown, with dark-colored, heavy, calcareous subsoils.

Areas which are too rough or rocky for agricultural use are mapped as Rough broken land.

List of series, showing origin and distinguishing characteristics.

Group.	Original material.	Distinguishing features.	Series.
Glacial.....	Unmodified drift..	Yellowish-brown subsoil; 1,300 to 1,700 feet altitude.	Barnes.
Do.....	do.....	Light-gray subsoil; 1,700 to 2,200 feet altitude..	Williams.
Do.....	do.....	The drift underlain by and mixed with shale..	Edgeley.
River flood plains.....	Recent alluvium..	Heavy, dark subsoil; large, flat bottoms.....	Lamoure.
Glacial lake and river terrace.	Old alluvium.....	Well drained; gravel substratum droughty	Sioux.
Do.....	do.....	Well-drained, silty, high river terrace, not droughty.	Bearden.
Do.....	do.....	Poorly drained; black soil; gray mottled subsoil.	Fargo.
Do.....	do.....	Poorly drained, dark-brown or drab soil; drab subsoil, underlain by gravel.	Maple.
Do.....	do.....	Poorly drained; gray or mottled subsoil; alkali; not deep to shale.	Rogers.
Glacial.....	Eolian deposits....	Sand reworked and heaped by wind action; loose, droughty.	Valentine.

The following table gives the name and the actual and relative extent of each soil type mapped in Dickey County:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Barnes loam.....	230,400	31.5	Lamoure silty clay loam.....	7,936	1.1
Barnes silt loam.....	137,664	18.8	Lamoure clay.....	7,808	1.1
Williams fine sandy loam.....	56,000	7.7	Bearden fine sandy loam.....	4,480	.6
Bearden fine sand.....	36,416	5.0	Maple clay loam.....	4,352	.6
Williams loam.....	32,448	4.4	Bearden very fine sandy loam.....	3,968	.5
Fargo silty clay.....	32,000	4.4	Lamoure silt loam.....	3,904	.5
Barnes very fine sandy loam.....	29,248	4.0	Lamoure silty clay.....	3,840	.5
Valentine fine sandy loam.....	26,368	3.6	Bearden loamy fine sand.....	3,712	.5
Barnes silty clay loam.....	23,552	3.2	Lamoure very fine sandy loam.....	3,520	.5
Rough broken land.....	22,336	3.1	Sioux silt loam.....	3,008	.4
Sioux loam.....	12,224	2.4	Sioux sandy loam.....	1,408	.3
Colluvial phase.....	4,992		Colluvial phase.....	832	
Edgley loam.....	16,000	2.2	Valentine fine sand.....	2,176	.3
Rogers silty clay.....	10,048	1.4	Bearden silt loam.....	1,472	.2
Sioux gravelly loam.....	1,984	1.1	Sioux fine sandy loam.....	640	.1
Colluvial phase.....	5,504				
Rolling phase.....	640		Total.....	730,880	

LAMOURE VERY FINE SANDY LOAM.

The soil of the Lamoure very fine sandy loam is about 16 inches deep, and consists of a dark-brown very fine sandy loam to fine-textured loam which is loose, smooth, and friable. The subsoil is a grayish-brown, friable, calcareous very fine sandy loam, grading into a slightly heavier, fine-textured loam, faintly mottled with gray. Still heavier strata occur at greater depths.

This type occurs mainly in the first bottoms of Maple River, which are overflowed about once in five years. One area lies along Bearden Creek, and a smaller one at the mouth of Cottonwood Creek. In many places the bottoms are hardly broad enough to be cultivated, and are used for pasture or hay land. Where farmed, the crops common to the region, wheat, corn, barley, and oats, are grown. Wheat yields about 16 bushels and corn 30 to 35 bushels per acre. The soil is well suited to corn, as it is deep and mellow. This type is usually sold with other soils, and its value is lowered somewhat by the irregular shape of the areas. It is held at about \$35 an acre.

LAMOURE SILT LOAM.

The Lamoure silt loam is typically a dark-brown or grayish-brown, friable silt loam. Below a depth of 14 inches it gradually becomes more compact and slightly heavier in texture, and grades into a dark grayish brown silty clay loam or silty clay, slightly mottled with

grayish white at about 30 inches. The subsoil is highly calcareous. This is the lightest colored soil in the Lamoure series, and is sometimes light grayish brown at the surface. In places, especially along the Maple River east of Ellendale, it approaches a very fine sandy loam in texture. Along the James River it occupies the slight natural levees which often occur on the outside of large bends. This is an easy soil to cultivate, except that the fields are irregular in shape because of the meanders of the streams. It is naturally well drained, but is not droughty. It is particularly suited to alfalfa, because of the deep, porous soil and subsoil and the abundance of moisture in the deep subsoil. Corn and wheat and other small grains are grown, and the yields almost equal those on the Lamoure silty clay. This land is valued at \$40 to \$50 an acre.

LAMOURE SILTY CLAY LOAM.

The Lamoure silty clay loam comprises the undifferentiated material occurring in the flood plains of the smallest waterways and in the slightly lower areas which exist along some of the larger streams. The soil usually is dark brown to black in color, and ranges from a fine sandy loam to a heavy loam in texture. The subsoil below 12 or 16 inches usually is grayish brown, mottled with gray and brown, and varies in texture even more widely than the soil. Sometimes sandy or gravelly strata occur below 30 inches.

This type occurs along practically all the smaller streams, but the bottoms are sometimes discontinuous. The small areas are often included in fields with other, more extensive soils. The larger bottoms are used for pasture. Some wild hay is cut, yields of a little more than 1 ton per acre being obtained. The two large areas of this type associated with the Edgeley loam are a little better than other bottom soils in the same localities, but are not so productive as some more typical areas.

The value of this type depends on the surrounding land, and ranges from \$20 to \$35 an acre.

LAMOURE SILTY CLAY.

The Lamoure silty clay is a dark-brown to black, friable silty clay, which grades at about 16 inches into a dark-brown or dark-drab, compact silty clay to plastic clay. It is faintly mottled in the lower depths with light-gray material, which consists in part of soft lime concretions. This is an alluvial soil occurring along the James River, and at several points along the Maple River. It usually lies along the stream, especially in the bends. Good drainage results from the proximity of the river channel and from the gentle slope of the surface to the lower land occupied by the Lamoure clay.

This soil, though inextensive, is the most desirable type in the county. Because of its friability, it is easy to till. While well drained, it is able to withstand severe droughts. The principal crops grown are wheat, corn, and barley. In average years yields of 20 bushels of wheat, 35 bushels of corn, and 32 bushels of barley per acre are obtained. Alfalfa has been grown successfully on a small scale, giving three cuttings of about 1 ton each.

Farms consisting in large part of this type are valued at \$50 to \$60 an acre.

LAMOURE CLAY.

The soil of the Lamoure clay to a depth of 9 inches is a black or very dark drab clay which is plastic when wet and cracks or crumbles into angular fragments when dry. Below 9 inches the subsoil has much the same color and texture as the soil, consisting of dark-drab or brown clay slightly mottled with gray and becoming slightly lighter colored with depth. The subsoil is highly calcareous, effervescing strongly in acid, and commonly contains small pieces of shale.

Rather extensive areas of this type occur along the James River in the vicinity of Oakes and north of this place, with several small bodies near Ludden and at the state line.

The Lamoure clay is the most poorly drained type in the series. It usually occupies that part of the bottom farthest from the stream and adjoining the hills, where it receives drainage waters from the upland, the run-off of such water being prevented by the slight natural levee at the river bank. The wettest areas of the type are indicated on the soil map by the marsh symbol. In these wet places there is an accumulation of alkali which causes the land to have a somewhat lower value. The marshy areas support a dense growth of grass, which is cut for hay, yielding 1 to 2 tons per acre.

Where the type is drained it produces good yields of all small-grain crops, but it is not so desirable for intertilled crops, such as corn, because it is difficult to cultivate. Yields of 15 to 25 bushels of wheat, about 25 bushels of barley, 35 bushels of oats, and 25 bushels of corn per acre ordinarily are obtained. Crops are more certain in dry seasons on this type than on any other soil in the county. This type is valued at about \$50 an acre.

BEARDEN FINE SAND.

To a depth of 16 to 20 inches the Bearden fine sand is a very dark brown to brown, loose, mellow fine sand or fine sandy loam. The subsoil is a lighter brown loamy fine sand, becoming yellowish brown, slightly mottled with gray and brown, and more loose and incoherent

in the lower part of the 3-foot section. The substratum consists of fine sand or coarser sand and extends to a depth of many feet. This type is the predominating soil in the region south of Oakes, but is not found in other parts of the county. The topography is level to very gently undulating. Along the north and west sides of the lake the type has a stronger, heavier, and more coherent soil, while toward the south and east it grades into the very loose "blow sands" mapped as the Valentine fine sand. The drainage is accomplished by the downward percolation of water, and the type is somewhat droughty. This type is too light in the subsoil for the typical Bearden soil, and not light enough for the typical Sioux. It could, however, be classed with either series. The area at Oakes and one near Ludden are coarser than the remainder of the type and slightly more droughty, while in a large area lying along the James River south of Oakes, the soil for a distance of about 2 miles from the river is finer in texture than the main body of the type. The soil here is nearer a very fine sand than a fine sand. The value of the type would be greatly increased if it could be devoted largely to alfalfa. When firmly established alfalfa would protect the surface from destructive erosion by winds, and its long tap roots would reach down to the abundant supply of ground water in the porous substratum within 10 or 15 feet of the surface. Experimental plots of alfalfa show that it can be grown in this region, though there is danger of the seed being covered too deeply and the small plants being smothered out in the loose surface before it is firmly established in the soil.

Soil moisture is easily conserved, so that corn does not suffer when the rainfall is well distributed. Small grain grows rather short and thin, and the heads are not large. Millet is a better source of hay than the native grasses. Yields of 8 or 9 bushels of wheat, 25 bushels of corn, 17 bushels of barley, 25 bushels of oats, and three-fourths to 1 ton of millet hay per acre are reported. The areas most subject to wind erosion are kept in grass, and yield about one-half ton of prairie hay per acre.

This soil type is also well suited to the production of corn and potatoes. Although it is apt to be droughty in some seasons for small grain, there is usually enough moisture for the production of cultivated crops. When cultivated crops are grown it is a good practice to cover the land with manure during the winter so that drifting will be checked in the spring. A fairly good crop of oats or durum wheat can usually be obtained on corn or potato ground handled in this way. Winter rye could be seeded in the stubble of this wheat or oats. If seeded very early in some years there would be moisture enough to obtain a stand of sweet clover. If a stand

is obtained it should produce a good crop of hay or seed or could be used for pasture. It makes especially good hog pasture. The sweet-clover land should not be plowed until the spring after the sweet-clover crop is produced. By following out some such cropping system drifting of the soil can be controlled to some extent. If the land is manured with 8 or 10 loads of manure per acre once in four years the soil will become more coherent in structure and less inclined to drift when such a cropping system is followed.

A demonstration farm was established on a sandy soil type similar to the Bearden fine sand in the vicinity of McLeod, in Ransom County, in 1909. The surface of the soil is more rolling and the sand is inclined to drift more than in the areas of this kind in this county, and the water table is nearer the surface on some parts of the farm. No rotation has been established on this farm, but experiments have been conducted to determine the adaptability of this soil for the production of various crops. These results have been obtained under conditions very similar to those in Dickey County and furnish an index of the adaptation of crops to sandy soils in the present survey.

The experiments have been carried on from 2 to 5 years and the number of trials has been from 3 in the case of field peas to 20 in the case of wheat.

The average yield of oats is 28 bushels, of field peas $9\frac{1}{2}$ bushels, sugar beets about $11\frac{1}{2}$ tons, potatoes 153 bushels, and of millet $1\frac{1}{2}$ tons. Winter wheat yields 8 and spring wheat $9\frac{1}{2}$ bushels, respectively. Less extended trials with redtop show that where the water table is sufficiently near the surface yields of $1\frac{1}{2}$ to 2 tons per acre of hay can be produced. Sweet clover has been grown successfully.

The average income per acre from all comparable crops in these experiments are as follows: Wheat, \$7.51; oats, \$8.26; barley, \$6.65; rye, \$5.75; flax, \$11.05; potatoes, \$84.55; and corn, \$11.09.¹ The income derived from oats and barley covers the cost of production, flax and corn have a slight margin of profit, and potatoes are the most profitable crop grown.

The typical Bearden fine sand in this county is better suited to small grain than the soil of the McLeod demonstration farm, and such crops usually yield fairly well when grown in a rotation containing corn and alfalfa or sweet clover. Oats and durum wheat are probably the best small grains to grow.

This land is held for about \$25 an acre.

¹ One and one-half tons of fodder is calculated as being worth as much as 1 ton of hay.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of this type:

Mechanical analyses of Bearden fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351474.....	Soil.....	0.0	1.4	1.2	28.8	53.2	10.8	4.7
351475.....	Subsoil.....	.2	2.6	2.4	24.6	52.0	13.0	5.1

BEARDEN LOAMY FINE SAND.

The surface soil of the Bearden loamy fine sand is a dark-gray or black, loose, calcareous fine sand or loamy fine sand 8 to 10 inches deep. The subsoil to an average depth of 20 inches is a light-brown, loose, incoherent fine sand, below which depth it becomes yellowish brown mottled with gray and brown. The material of both sections of the subsoil effervesces in acid. There is seldom even a thin layer of heavier material in the soil section or substratum. The type is poorly drained, as it occurs in depressions, and even in dry seasons the sand is usually saturated at a depth of 3 or 4 feet. Unlike most depression soils, this type does not contain sufficient clay to make the sand coherent, and when the sod is broken the soil is likely to drift. On account of its moist nature and high water table, this land produces good crops of hay. Although some areas have been broken, most of them have reverted to grass, and furnish good hay and pasturage. During the summer of 1914, sec. 24, R. 59, T. 129, consisting largely of Bearden loamy fine sand, supported 280 head of beef cattle. Land of this type should yield 1 ton of prairie-grass hay per acre. Land of the Bearden loamy fine sand is valued at \$20 to \$25 an acre.

BEARDEN FINE SANDY LOAM.

The surface soil of the Bearden fine sandy loam typically consists of a black, dark-brown or dark-drab, loose fine sandy loam, 10 to 14 inches in depth. The subsoil is a light-brown or grayish-brown, calcareous fine sandy loam, grading into a gray silty or sandy clay slightly mottled with drab and brown. This heavy layer usually gives way to a fine sandy loam heavily mottled with brown at 32 to 40 inches. The large areas of this soil 3 or 4 miles southeast of Oakes do not occupy distinct depressions, but have a very flat topography and a heavy layer in the subsoil that retards the downward percolation of rain water. The areas farther south of Oakes usually are depressed slightly below the general level of the plain and are not so well drained as the areas to the north. They are used mainly for

growing wild hay, yielding about $1\frac{1}{2}$ tons per acre. Some alkali spots occur.

Land of this type near Oakes has a high value because of its convenient location as well as its good subsoil. It is a very good corn soil, as it warms up early in the season and is easy to cultivate. There is always an abundance of moisture under the loose surface soil. Wheat yields about 10 bushels and oats 20 to 25 bushels per acre. The wetter areas are kept in prairie sod and produce about 1 ton of wild hay per acre. Unimproved land of this type is valued at \$20 to \$25 an acre.

BEARDEN VERY FINE SANDY LOAM.

The typical soil of the Bearden very fine sandy loam is a dark-brown to black, very smooth, friable, and uniform-textured very fine sandy loam, with a depth of 12 to 16 inches. The subsoil is a dark grayish brown, highly calcareous very fine sandy loam, about 12 to 24 inches thick, changing rather abruptly to a light-gray, compact and somewhat impervious, highly calcareous silty clay or silty clay loam. This heavy layer continues below 3 feet, but changes to yellowish brown with depth. The topography is flat to gently undulating, and the surface drainage usually is good.

This type occurs in the southeastern part of the county within the smooth area known as the bed of Lake Dakota. The soil is composed of the fine sandy particles which have been washed or blown over heavier sediments laid down in the old lake or as river terrace material. The principal areas are located about 3 miles south of Oakes, 3 miles southwest of Ludden, and about 4 miles southeast and 4 miles north of this place.

This type is suited to all the general farm crops common to the region, and produces good yields. Corn yields about 20 bushels, wheat 10 to 15 bushels, and oats about 30 bushels per acre. Wild hay yields three-fourths ton and millet $1\frac{1}{2}$ tons of good hay per acre.

The soil of the Bearden very fine sandy loam is less likely to drift during high winds than other soils in this region, and it is unusually retentive of moisture.

This is a good corn and alfalfa soil, and millet and sweet clover can be used to good advantage in some cropping systems. The organic content should be maintained by the growing of alfalfa and sweet clover and the application of farm manure. Some of the rotations suited to this type are: (1) Corn or potatoes 1 year, wheat 1 year, oats 1 year, sweet clover 1 year, and alfalfa 4 years; (2) corn or potatoes 1 year, barley 1 year, oats 1 year, millet 1 year, and alfalfa 4 years; (3) corn or potatoes 1 year, millet 1 year, oats 1 year, sweet clover 1

year, and alfalfa 4 years; (4) corn or potatoes 1 year, barley 1 year, oats 1 year, sweet clover 1 year, and brome-grass pasture 4 years.

This is the most valuable soil of this part of the county. It is held at \$30 an acre.

BEARDEN SILT LOAM.

The Bearden silt loam is a dark-brown to black, smooth, friable silt loam, with a depth of 10 to 16 inches, underlain by a yellowish-brown or oat straw colored, highly calcareous silt loam, which is slightly more compact and grades downward into a silty clay loam faintly mottled with gray and brown. The substratum usually resembles the subsoil, but fine sandy or gravelly layers may occur below 5 feet.

The type occurs mainly in the northeastern part of the county, the largest development being found south and southwest of Glover along the James River. This is a terrace soil and, while not eroded, usually is not level, but is gently sloping or undulating. It is often elevated more than 20 feet above the low bottom lands and probably was formed by the James River when it flowed at a much higher level, though the soil material has a structure resembling that of wind-laid deposits. It is essentially like the Barnes silt loam, differing only in the process by which the soil material was deposited.

The Bearden silt loam is a strong soil of good water-holding capacity, easy to till and suited to all crops usually grown in the region. Wheat yields about 15 bushels per acre, corn 35 bushels, and oats and barley in proportion. This land is valued at \$40 an acre.

Results of mechanical analyses of samples of the soil and subsoil of this type follow:

Mechanical analyses of Bearden silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351420.....	Soil.....	0.2	0.6	0.9	5.2	6.6	61.6	24.7
351421.....	Subsoil.....	.1	.4	.8	7.9	9.2	61.4	20.3

The following sample contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 351421, 15.20 per cent.

FARGO SILTY CLAY.

The soil of the Fargo silty clay is a black to very dark brown, friable to compact, usually calcareous silty clay 16 to 24 inches deep. It is sometimes faintly mottled with rusty brown. The subsoil is a

gray or drab, plastic, calcareous silty clay, becoming lighter in texture and heavily mottled with yellow, brown, drab, and light grayish with depth. This type is poorly drained and is so depressed that it receives the run-off from the surrounding land. The areas range in size from 2 or 3 acres to more than a section. The type is underlain by impervious clays or till where surrounded by glacial soils. Areas of the Fargo silty clay are scattered through all parts of the county, except on the well-drained east slope of the Altamont moraine. They are especially numerous near Clement and in the "hill country," or Altamont moraine. Where surrounded by the Williams soils the Fargo silty clay is less black and more drab in color than in typical areas. In some areas the black soil extends to a depth of 3 feet or more. One large area on the slope 4 miles south of Merricourt is similar to the Barnes silty clay loam, except that it has a decidedly ashy gray colored subsoil. A small area about 6 miles northeast of Fullerton, in secs. 1 and 36, Tps. 132 and 131, R. 61 W., is somewhat lighter in texture than the typical soil, and the same is true of a small area in section 20 of the former township, as well as of a long strip about 5 miles west of Ludden.

The majority of the areas of this type are too wet in the spring to be seeded to wheat, but are used for the production of hay. Hardly a farm is without one or more of these areas, which yield from 1 to 2 tons of prairie hay per acre. Since the run-off from the surrounding land has been greatly decreased by breaking the prairie sod and preparing a loose layer of soil which absorbs the rain, some of the areas of Fargo silty clay have become dry enough to cultivate. Good yields are obtained, although where grain is grown the straw tends to grow too rank, and corn is subject to injury by early frosts. In favorable seasons wheat yields about 30 bushels, corn 25 to 30 bushels, oats about 70 bushels, and barley about 40 bushels per acre in the better drained areas.

An average value of this type, based on its use for hay, is \$25 to \$30 an acre.

Average results of mechanical analyses of samples of the soil and subsoil are given in the following table:

Mechanical analyses of Fargo silty clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351495, 351496.....	Soil.....	0.5	2.1	1.9	9.2	7.6	44.0	34.8
351497, 351497.....	Subsoil.....	.1	.6	.6	3.3	9.6	55.9	30.0

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 351447, 20.29 per cent; No. 351497, 16.88 per cent.

SIoux LOAM.

The Sioux loam is a light to heavy loam, very dark brown to black in color, the black layer having an average thickness of about 12 inches, though in exceptional cases it extends to a depth of 2 feet or more. The subsoil is a yellowish or grayish-brown, calcareous loam and there is in many places a compact layer just above the gravel substratum. The gravel is often incrustated with lime. The type is fairly retentive of moisture. This soil occurs typically on flat terraces along Bearden Creek and other watercourses where beds of gravel were deposited in glacial times. Wherever the type occurs along the outer boundary of a valley, especially along James River and Bearden Creek, it has received more or less wash from the adjacent hills covering the original river terrace with a layer of silty material. This material is essentially the same as that beneath, so far as its source and composition are concerned, though the greater part of the accumulated wash is dark in color, making the dark-colored layer thicker and also burying the gravel layer deeper than in the uncovered terraces. The soil is somewhat better, therefore, than the typical soil, though the moisture supply may not be the same. The topography is sloping rather than flat. The areas north-east of Oakes are slightly lighter in texture than elsewhere.

The Sioux loam has a good, loose, porous structure, even where it is broken when wet, and is easily worked into a good seed bed. The soil contains about 10 per cent of organic matter and is quite productive. Yields are reduced by the droughtiness of the soil and are slightly lower than on the Sioux silt loam. Corn yields about 25 bushels, wheat 12 bushels, barley 20 bushels, and oats 27 bushels per acre. Unimproved land of this type sells for about \$30 an acre.

Sioux loam, colluvial phase.—Along the foot of the Altamont moraine a belt of soil is mapped as the Sioux loam, colluvial phase. This belt does not extend along a stream, but is traversed by a number of streams, which flow directly across it. This is colluvial material which is mapped as Sioux because of its water-laid origin and the occurrence of a layer of gravel a few feet below the surface. It is a loam in texture and has the other characteristics of the Sioux loam. Its topography and the crops grown on it, as well as the yields obtained, are about the same as on the typical soil. This phase is shown on the soil map by parallel rulings over the Sioux loam color.

SIoux GRAVELLY LOAM.

The Sioux gravelly loam is a dark-brown to black, calcareous gravelly loam or sandy loam grading at 2 to 6 inches into an earthy gravel bed with lime-incrustated pebbles, and at greater depths

into cleaner and looser gravel. The gravel particles are from one-fourth inch to 5 or 6 inches in diameter. The topography usually is level, but some areas occur on small ridges or along the slopes of terraces.

This type is not suited to crop production, because it is too gravelly to cultivate and too droughty to produce profitable crops. It furnishes scant pasturage. The underlying gravel beds are sources of good road-surfacing material and railroad ballast, but the gravel does not make good concrete, because it contains soft shale pebbles. For farming the type is valued at about \$10 an acre.

A beach-sand variation of this type is developed in a number of places, mainly in the higher country west of the Altamont escarpment. It is found in very narrow belts that were originally small, permanent lakes. Most of these areas have become mere marsh land on account of the decreased inflow of water due to the breaking up of the prairie sod and the resulting greater absorption of the rainfall by the soil. These belts consist of 4 to 6 inches of a loose gravelly loam or sandy loam top layer, usually dark brown in color, underlain by a loose gravel subsoil. The soil is very rarely cultivated. Yields of small grain do not average more than 5 or 6 bushels per acre. The soil usually is covered with grass in its native condition, though the more recently formed areas are barren of vegetation.

Sioux gravelly loam, colluvial phase.—In character of soil this phase does not differ essentially from the main type. It is black or dark brown in color and gravelly to sandy in texture, and is underlain by gravel. It lies at the foot of the Altamont moraine, stretching as a narrow north and south belt in Tps. 129 and 130, R. 65 W., with smaller areas north of the main belt. This belt extends across rather than along the minor drainage ways. It slopes eastward and has a somewhat steeper surface than the typical soil. It is slightly eroded in places. Agriculturally it has about the same value as the typical soil. (See Pl. I, fig. 2.)

Sioux gravelly loam, rolling phase.—The soil of the Sioux gravelly loam, rolling phase, is a very dark brown to black gravelly loam or gravelly sandy loam, with a depth of 4 to 6 inches. The subsoil is a grayish-brown, earthy gravel, grading quickly into beds of stratified gravel, which are grayish, yellowish or rusty brown in color, usually effervescing freely in acid, and containing as a rule many lime-coated pebbles.

This phase occurs on small, rounded kames and long narrow eskers where the water escaping from the glacier front or flowing through cracks in the ice sorted and deposited the material of these gravelly hills. It is scattered over the county, usually associated with morainic hills, especially in the low hills of the Antelope moraine, which extend through the county west of Ellendale and near Monango. It

is a poor soil and is seldom cultivated except where the knolls are very smooth and occur in a field made up mainly of good soil. Because of the droughty nature of the subsoil, the yields of all crops are light, and even the prairie grasses make a poor growth. The phase is worth very little for farming, but is a source of good road-building material.

SIoux SANDY LOAM.

The typical Sioux sandy loam is a brown, dark-brown or black, loose, medium sandy loam or loamy sand, 8 to 12 inches deep, underlain by a loose and incoherent medium sand, yellowish or grayish brown in color, and grading into coarse sand or fine gravel. This soil was formed by weathering and the accumulation of vegetable matter on the sand bars of glacial streams. The topography is generally level. The type occurs along the James River and some of the other streams of the county. Like the fine sandy loam, neither the soil nor the subsoil usually effervesces in acid.

The typical soil and the colluvial phase, described below, have about the same value, ranging from \$20 to \$25 an acre. They are also about equal in productiveness, yielding 7 to 9 bushels of wheat, about 18 bushels of corn, and 15 to 20 bushels of oats per acre.

Sioux sandy loam, colluvial phase.—Several small areas of the Sioux sandy loam occur on colluvial slopes at the foot of the Altamont moraine, in the western part of the county. The soil of these areas is the same in character as the typical, the only difference being in its position at the foot of the slope, where it has been laid down as colluvial wash rather than as a terrace. The topography is smooth.

SIoux FINE SANDY LOAM.

To a depth of 8 to 12 inches the Sioux fine sandy loam is a loose, mellow fine sandy loam. The subsoil is a light-brown to yellowish-brown fine sandy loam, becoming somewhat heavier and more compact with depth. While the type occurs on a gentle colluvial slope, the rather uniform sandy nature of the soil indicates that much of it was carried there by the wind, instead of being derived entirely from the heavier material of the hills above.

The Sioux fine sandy loam is mapped in several areas along the upper course of the James River. The substratum of the type usually is composed of sands instead of gravel and the subsoil does not seem to be so calcareous as most of the soils in this region. It rarely effervesces in acid.

This type is of too small extent to be of general importance, but it produces fair yields of all the crops common to the region. Wheat yields about 11 bushels, and other crops give proportionate yields per acre. This land is held for about \$25 an acre.

SIOUX SILT LOAM.

The Sioux silt loam is the heaviest member of the Sioux series in Dickey County. The soil is a dark grayish brown silt loam containing considerable sand. At 10 to 16 inches this grades into a light-brown or yellowish-brown silt loam or heavy loam. The subsoil usually is more compact and heavier in the lower part and a bed of gravel is encountered at a depth of 30 to 40 inches. Both soil and subsoil are sufficiently calcareous to effervesce in acid.

This soil is typically developed at several points along the James River and Bearden Creek. The area 2 miles northeast of Oakes is lighter than typical, approaching a very fine sandy loam, and is underlain by beds of sand. Several areas of the type mapped along small draws on the slope below the Missouri Plateau merge with the adjoining soil in such manner that they can be located only by boring down to the gravel beds. They occupy positions essentially like those occupied by the colluvial phases of some of the Sioux types, and could have been separated as colluvial phases of the silt loam if of sufficient extent.

This type is not very droughty, owing to the thick layer of close-textured soil and the slight tendency toward a hardpan just above the gravel beds. It is well drained and is an easy soil to handle. In seasons of average rainfall it produces practically as good crops as the Barnes soils. Wheat yields from 15 to 25 bushels, oats 30 to 50 bushels, flax 6 to 7 bushels, barley 25 to 40 bushels, and corn about 28 bushels per acre, in favorable years.

This type sells for \$30 to \$40 an acre, or more where the farm improvements are good.

ROGERS SILTY CLAY.

The Rogers silty clay is a variable type, but the average soil is a very dark brown or dark-drab to black, calcareous silty clay to clay 10 to 14 inches deep and slightly mottled with gray. The subsoil is a dark-gray, compact, plastic, highly calcareous silty clay, mottled with gray and yellowish gray below 24 inches. There are heavy black "gumbo" spots in places, and in other places a yellowish clay is encountered near the surface. The surface is often veneered with streaks or spots of sand and is light gray with the alkali incrustations associated with the type. In places the underlying clays directly overlie bedded shale and elsewhere they pass into till. The Rogers silty clay occurs mainly in areas within or near the strip of Edgeley loam west of Monango and Ellendale, where it occupies wide flats.

A variation of the Rogers silty clay occurs on the Plateau as the lake-bed deposits of depressions which recently contained several feet

of water. Such areas resemble the Fargo silty clay, but are more highly impregnated with alkali. Most of the type is used for pasture or hay land, though some of the smaller areas occurring within bodies of Barnes soils are cultivated. They are too wet and cold to produce good crops of corn, and the alkali seems to stunt the growth of small grains. The type supports a growth of coarse grasses. This land is valued at \$15 to \$18 an acre.

Below are given the results of mechanical analyses of samples of the soil and subsoil of the Rogers silty clay:

Mechanical analyses of Rogers silty clay.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351416.....	Soil.....	1.0	3.0	2.4	15.9	19.0	28.6	21.1
351417.....	Subsoil.....	.6	1.4	1.2	10.2	15.6	34.3	21.4

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 351416, 6.29 per cent; No. 351417, 23.36 per cent.

MAPLE CLAY LOAM.

The Maple clay loam has a dark-drab clay loam soil, 8 to 15 inches deep, and a drab, close-structured, waterlogged subsoil which becomes lighter drab and mottled with gray and brown at about 30 inches, where it usually grades into gravelly or sandy strata. This gravel does not subdrain the soil, because the type occurs in the bottoms of old drainage channels or lakes. Where it occupies long, comparatively narrow troughs there is some surface drainage by streams, and the soil is somewhat lighter textured, but where it occupies lake beds the drainage is poorer and the soil is often a silty clay in texture.

Areas of the Maple clay loam occur in the northeastern corner of the county. An area occurs between Fullerton and Ellendale, and several areas are mapped in the vicinity of the Edgeley loam. Two areas of a heavy variation are encountered in German Township, in the western part of the county.

Owing to its poor drainage, this type is not extensively cultivated. It furnishes some pasturage and produces about a ton of prairie hay per acre. Where cultivated the yields average 7 or 8 bushels of wheat, about 15 bushels of barley, and 18 bushels of oats per acre. The soil is not suited to corn. This type ranges in value from \$10 to \$25 an acre, according to the drainage and the value of adjoining land.

BARNES VERY FINE SANDY LOAM.

The Barnes very fine sandy loam consists of 10 or 12 inches of dark-brown to black, loose, mellow very fine sandy loam or fine-textured loam, underlain by a lighter brown, loose, porous loam which grades at about 24 inches into light-yellowish or grayish-brown loam or fine sandy loam. This lower material effervesces freely in hydrochloric acid. The subsoil and substratum usually have the same texture and structure, but in places the material becomes heavier and more compact with depth. Several areas, associated with old drainage ways about 6 miles northeast of Oakes, are characterized by unusually deep, smooth, uniform-textured soils, possibly of wind-blown origin.

The largest areas of this type occur around Monango and along the upper course of the Maple River. Other areas are found north and northeast of Fullerton, west and southwest of Ellendale, and scattered along the slope west of the Edgeley loam. The topography is level to gently undulating, and the type is well drained by draws, depressions, and a porous substratum. Areas of this type merge with the Barnes loam on the one hand and with the Valentine fine sandy loam on the other, and each type includes small areas of the others.

The Barnes very fine sandy loam is a strong soil, but crops suffer from prolonged droughts. While the wind shifts the surface material in plowed fields to some extent, it does no appreciable damage. The land is easily broken and cultivated. Land which has been devoted to small grains for several years is infested with Russian thistle and other weeds, but these can be largely eradicated by growing cultivated crops or millet. This type averages a little stronger and more retentive of moisture than the Valentine fine sandy loam, and is slightly less productive than associated areas of the Barnes loam. Corn should be planted to a greater extent on this type. It averages about 24 bushels, with maximum yields of about 35 bushels, per acre. Millet yields $1\frac{1}{2}$ tons per acre when the hay varieties are sown, while hog millet yields 20 to 25 bushels of seed per acre. Wheat yields average 9 or 10 bushels per acre, ranging from 3 or 4 bushels in dry years to 15 or 16 bushels in more favorable seasons. Oats average 20 to 25 bushels, barley about 16 bushels, and winter rye 13 or 14 bushels per acre.

This land has an average value of about \$30 an acre, with a higher value where it is highly improved and favorably located with respect to markets and shipping points.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Barnes very fine sandy loam:

Mechanical analyses of Barnes very fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351402.....	Soil.....	1.6	6.0	5.6	30.5	16.2	32.2	7.4
351403.....	Subsoil.....	.8	4.4	5.2	37.6	15.2	23.8	12.1

The following sample contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 351403, 4.25 per cent.

BARNES LOAM.

The Barnes loam is a dark-brown to black, mellow loam, 8 to 12 inches deep, underlain by lighter brown, yellowish-brown or greenish, highly calcareous, moderately compact loam. The substratum is somewhat heavier and more compact and consists of glacial till resting upon shale. The till is 5 to 20 feet thick near the Edgeley loam and 80 to 100 feet or more in thickness in the eastern part of Dickey County. There are several variations of this type. As mapped in Barnes County, N. Dak., it occurs on and about moraine areas, and a similar development is found in a few places in Dickey County. In such places it has a slightly thinner soil than typical on a rolling and hilly topography, and a relatively large number of stones and boulders on the surface. Such areas occur east of Oakes and south of Guelph. Practically these same characteristics are found where the type is mapped in the old drainage way or spillway just west of Clement. Many of the small areas of this type scattered through areas of the Barnes silt loam consist of small, eroded, and stony hills or knobs. As a rule these areas have a comparatively heavy and compact subsoil, which is often mottled with gray. Although stones are numerous on the surface, they do not interfere seriously with cultivation and can be removed economically. This variation of the type is less valuable than the Barnes silt loam.

Another variation of the Barnes loam is encountered in the James River Valley and in Ada Township, where it corresponds closely in depth of soil, texture and structure of subsoil, topography, and general agricultural value to the adjoining areas of the Barnes silt loam. The only difference is that the soil is somewhat coarser textured. These areas constitute good agricultural land.

A variation is found along the Maple River and between that stream and the belt of Edgeley soils. Here the type is associated with areas of very fine sandy loam, and the areas of Barnes loam often contain spots of other material which are too small and unimportant to map separately. The subsoil and substratum are lighter, looser, and more porous than typical. The topography is generally level to gently undulating, except where the monotony of the plain

is broken by the low, rounded hills of the Antelope moraine. These hills occur as small knobs and discontinuous ridges in a strip passing 5 or 6 miles west of Ellendale and a little west of Monango. Where this variation of the Barnes loam is associated with the Edgeley and Rogers soils it is less valuable, but it grades into better, stronger land toward the east. The Barnes loam occurs east of the Altamont escarpment and is the predominant soil in ranges 61, 62, 63, and 64.

In a general way the type of farming on the Barnes loam is the same as on the silt loam of the series. The two types merge so gradually that the boundaries are necessarily arbitrary in many places. However, the loam on the average is somewhat less productive for all classes of crops than the silt loam.

The areas of the Barnes loam of rougher topography form an extensive area in prairie sod, which furnishes good pasturage or yields about a ton of hay per acre. Whenever the sod is broken the land is put in flax, which yields an average of 7 bushels of seed per acre. On the lighter variations near Ellendale many farmers have found hog millet to be a paying crop, averaging 25 bushels of seed to the acre. In addition, this crop may be seeded late, and it protects the ground from strong winds. Some farms on the Barnes soils are so badly infested with wild oats that yields of wheat and other small grain are decreased and millet is an excellent crop for such lands. Wheat averages 10 or 11 bushels on the lighter and more droughty areas and 13 or 14 bushels per acre on the better areas. In favorable years yields of 25 to 30 bushels have been obtained. Barley sometimes produces as much as 40 bushels per acre, but the average yield is about 20 bushels. Oats average 30 bushels, with occasional yields of 50 to 70 bushels per acre.

The Barnes loam is suited to much the same range of crops as the Barnes silt loam. At present it is cropped in much the same way. Being a coarser textured type it will require even more care in maintaining the organic matter. Some areas of this type will require special attention to avoid drifting or blowing, especially in the spring, although several other types in the county will require even more care than this in that respect. Broom-corn millet is grown quite successfully by some of the farmers in the county on this type. This is one of the best corn soils in the county, and alfalfa can be grown successfully on much of it. It is not as good a soil for small grain as the Barnes silt loam, and cultivated crops and forage crops will need to be grown more frequently in the rotation.

A demonstration farm was located on this soil type near Jamestown, in Stutsman County, in 1901.

The land was broken up in the spring of 1880 and cropped to small grains continuously with the exception of 1905, when it was summer fallowed. Wheat

was grown each of the following years until the spring of 1910, when it was taken for demonstration farm purposes. During all the time it was cropped no manure or other fertilizer had been applied to the land. The farm was thoroughly infested with wild oats and yellow mustard.¹

The rotation planned for this farm consisted of corn, 1 year; wheat, 2 years; clover or oats and peas, 1 year; and winter rye, 1 year. Ten loads of stable manure per acre were applied to the land for the corn crop. The last of the plots was manured for the 1913 corn crop and plot 2 has been manured the second time. The average yield per acre for the 6-year period was, wheat, 16.60 bushels; corn, 26.91 bushels; oats and peas, 2,000 pounds; and rye, 9.58 bushels.

The crop in 1909 was seriously injured by a hailstorm on July 31. In 1910 the rainfall was very light, so that the yields were low. The early part of the season of 1911 was quite dry, and there was very little available water stored in the soil because of lack of rain the preceding year. In addition to this the wheat crop was injured by rust. A good corn crop was produced in 1911, and the wheat on land that had grown corn the preceding year was fair. The last three years have been quite favorable. Corn has ripened in four years of six and produced a fair crop of fodder in 1912. The wheat crops have been fairly good. The wheat crop immediately following the corn crop has produced an average of over 4 bushels per acre more than that grown the second year after the corn. Timothy and clover have been seeded each year with the second wheat crop but a stand has been obtained in only 2 years of the 6. Oats and peas produced fair crops in 1909 and 1912, but yielded very little in 1910 and 1911 because of the dry weather. Winter rye has not given good results when seeded on land that grew peas and oats the preceding year.

During the years 1913 and 1914 the cost of producing the various crops in this rotation was calculated. As an average for the two years it has cost \$11.88 to produce an acre of corn in this rotation \$8.19 to produce an acre of wheat following the corn, \$7.03 to produce the second crop of wheat, \$5.07 per acre to produce clover and timothy, and \$7.57 to produce an acre of barley. The average income per acre was, wheat, first year following corn, \$12.01, or second year after corn, \$8.99, corn \$15.39, oats and peas \$10.41, and rye \$5.70.

While the corn crop has not shown a profit every year, it has produced enough in the good years so that as an average it has returned a profit. In fact it has been almost as profitable as the wheat crop which followed it, and the profit obtained from the wheat is largely due to the cultivation given to the corn the preceding year. This

¹ Third annual report of the Superintendent of Demonstration Farms for North Dakota, 1909, p. 34.

is supported by the fact that the first wheat crop following the corn returned on an average a profit of \$3.81 per acre while the second returned but \$1.86. This would indicate that 51 per cent of the profit obtained from the first wheat crop was attributable to the fact that corn instead of wheat preceded it. All things considered the corn crop has been the most profitable of any in the rotation for the entire period. The timothy and clover crops have returned a good profit in the years when a stand has been obtained, but a stand has been obtained but two years in five. For comparison the value of the fodder has been calculated in the years that ripe corn was produced. This amounted to \$6.04. It will be noted the crop is much more valuable when calculated on the basis of husked corn. This shows that it is much more profitable to grow a variety of corn that will ripen than to grow a late-maturing variety that will make only fodder.

Other rotations that could be followed on this soil type are as follows: (1) Corn 1 year, wheat 1 year, oats 1 year, and alfalfa 3 years; (2) corn 1 year, wheat 1 year, broom-corn millet 1 year, and alfalfa 3 years; (3) corn 1 year, barley 1 year, oats 1 year, and alfalfa 3 years; (4) corn 1 year, broom-corn millet 1 year, wheat 1 year, and timothy and clover 1 year; (5) corn 1 year, wheat 1 year, barley 1 year, and sweet clover 1 year.

Alfalfa is the best legume crop for this type and by having four fields, one of which is in alfalfa for three years, it can be worked into the rotation. It is possible that in some cases more than two grain crops can be grown after a cultivated crop, but most of the available data indicate that the third and succeeding crops are very uncertain, and the chances are against their being profitable.

The Barnes loam has an average value of about \$33 an acre for the land alone, but the improvements sometimes have a greater value than the land. Some good farms on this type are held for more than \$60 an acre.

BARNES SILT LOAM.

The Barnes silt loam is a dark-brown to black silt loam to heavy loam, underlain at an average depth of about 12 inches by a lighter brown or yellowish-brown silty clay loam or loam, often showing a shade of green and always highly calcareous. The deeper subsoil usually is somewhat heavier and spotted with accumulations of soft lime carbonate. Some crystalline stones and boulders occur on the surface and in the soil. About 10 per cent of the rock fragments on the surface are limestone, and the rocks embedded in the soil usually are incrustated with lime. The subsoil, at depths ranging from 1 to 2½ feet, effervesces with acid. The drift giving rise to this type was

laid down under the ice sheet, where it was leveled and subjected to the action of water from the melting ice.

The topography is level to undulating and the land usually is well drained as a result of the natural slope and existence of many depressions. On slopes the soil layer is often thinner than typical, and in sags the dark-brown color may extend to a depth of 20 inches. Practically all the type is available for agriculture, and it constitutes the best upland soil in the county. Farm buildings are good and there is a general appearance of prosperity in regions where the Barnes silt loam is the prevailing type. It comprises the greater part of the glacial soil of Wright, Yorktown, Hudson, Port Emma, James River Valley, Clement, and Bear Creek Townships. Several sections of this type occur 5 to 8 miles north of Fullerton; a large body lies between Ellendale and the Maple River; and other important areas occur on the gentle slope below the Missouri Plateau. In many places it is difficult to separate this type from the adjoining Barnes loam. These two soils are comparable in physical characteristics and in general value. However, the Barnes silt loam is very seldom spotted or associated with sandy loam soils, while patches of such soils are common in areas of the Barnes loam.

The Barnes silt loam soil has a very smooth feel, due to the 10 to 15 per cent of organic matter present. This high organic-matter content sometimes causes the soil to seem lighter than it really is while on the other hand it masks the sandiness of lighter phases of the type. Heavier phases clod when plowed too wet, but the clods are fairly easy to pulverize by disking and harrowing. Both the soil and subsoil are retentive of moisture, as is the underlying till which extends to depths of 20 to 100 feet before shale is encountered. Only insignificant alkali spots occur in this type.

From 70 to 80 per cent of the area of this type is devoted to small grains, while something less than 10 per cent is used for hay or forage. In this system of grain farming it is often necessary for the farmers to buy feed for the work stock. Wheat is the leading cereal and the chief money crop. Taking good and bad seasons the yield averages about 15 bushels per acre. Some of the best land often produces more than 20 bushels per acre, and yields of 35 to 40 bushels are sometimes reported. Barley would probably give better yields if it were given the same attention as wheat. Even with late seeding it averages 22 bushels per acre, and under exceptionally favorable conditions it produces 40 to 45 bushels. Flax, the crop usually sown on newly broken land, yields an average of 8 or 9, with a maximum of 15 to 20, bushels per acre. The acreage of corn is steadily increasing as the bad effects of growing wheat year after year on the same land are more generally recognized. Early maturing varieties well suited to this climate are being introduced, and many silos are being

erected. The average yield per acre is about 28 bushels, but 40 bushels or more may be obtained. A large acreage of oats is grown each year, chiefly for horse feed. Oats ordinarily yield about 32 bushels per acre, with maximum yields of about 50 bushels on the best land during favorable seasons. Potatoes are grown for home use and to supply local markets. They average nearly 90 bushels per acre, and some farmers report yields of 150 to 200 bushels. The number of cattle kept on this type is increasing. Millet and brome grass yield about $1\frac{1}{2}$ tons of hay per acre. Timothy and clover are of minor importance and yield about a ton of hay per acre. Alfalfa is grown on a very small scale, and yields about 2 tons of hay per acre. This crop should have a more important place in the present system of farming.

The Barnes silt loam has a comparatively high water-holding capacity. The upper 40 inches of the soil is capable of retaining the greater proportion of the average rainfall of the region. For this reason there is very little percolation through this soil, and if the surface material is kept in a granular condition, so that it will absorb the rainfall, there need be little loss of water where the crops are grown in such sequence that the water in the soil will be utilized and not allowed to evaporate.

This soil is especially suited to small-grain production, but as these crops have been grown almost exclusively since the land was broken, satisfactory yields have not always been obtained on some farms on this soil type in recent years. In its native state this soil contained a large amount of organic matter. Practically no manure has been added and very few grass or legume crops grown to keep up this supply. The only organic matter remaining is that which has withstood decay during the time the land has been under cultivation.

The soil must be improved by the growing of legume and grass crops and cultivated crops in the rotation. In addition to this all roughage, such as straw, etc., should be converted into manure and returned to the soil. Corn or some other cultivated crop should be grown once in four or five years, and if possible some hay crop should be grown at least that often. Alfalfa could be worked into the rotation slowly by leaving it down for four or five years and then plowing it under and using on this field the rotation followed on the remainder of the farm. Alfalfa can be grown on another field in the meantime. The manure produced when the alfalfa is fed can be applied to such parts of the farm as may be in need of it in order to be kept in a well-balanced state of fertility.

A demonstration farm has been located on this soil type in the N. W. $\frac{1}{4}$ sec. 30, T. 131, R. 59 since 1910.

The time it was broken up as prairie sod is unknown, but it probably was in the early eighties. Since the spring of 1910 it has been cropped with wheat,

oats, barley, and millet. It has never been manured. It has never been in a cultivated crop, and is not infested with any noxious weeds with the exception of wild oats, although these are quite abundant.

A 5-year rotation consisting of corn, 1 year; durum wheat, 1 year; oats or winter rye, 1 year; Blue-stem wheat, 1 year (nurse crop for timothy and clover); timothy and clover or oats and peas, 1 year, was planned for this farm. This rotation has been followed as closely as possible. Ten loads of stable manure per acre have been applied to the land for the corn crop. The last of the five plots was manured for the corn crop of 1914.

It will be noted that corn has ripened in four years of the five, the average yield being 24.25 bushels. When figured at the average farm price for corn in North Dakota in the years in which it was grown, this gave an average return of \$12.13 per acre. Valued at its fodder equivalent, the crop was worth but \$6.13 per acre, 1½ tons of fodder being considered equal in value to 1 ton of hay.

Durum wheat following the corn has produced an average yield of 20.49 bushels per acre, worth \$16.58. This crop was grown in the best place in the rotation for small grain, and returned a larger income than any other crop in the rotation. Oats were grown in 1910 and 1911, two very dry years, so that the yields are no doubt below what could be expected in an ordinary year on this soil type. Rye grown in 1912, 1913, and 1914 produced an average yield of 18.41 bushels, worth \$10.88. Blue-stem wheat following oats or rye has averaged but 11.81 bushels per acre, worth \$9.42.

All crops were produced at a good profit in 1912 and a fair profit in 1913. With the exception of the millet hay, all crops returned a good profit in 1914. As an average durum wheat has been the most profitable crop. This is largely due to the fact that it occupies the place in the rotation that is most favorable for small grain, and a large part of the profit is attributable to the cultivation given the corn crop during the previous season.

Some other rotations suggested for this soil are as follows: (1) corn 1 year, wheat 1 year, wheat 1 year, oats 1 year, alfalfa 4 years; (2) corn 1 year, wheat 1 year, barley 1 year, oats 1 year, brome 4 years; (3) corn 1 year, wheat 1 year, broom corn 1 year, barley 1 year, alfalfa 4 years; (4) corn 1 year, wheat 1 year, wheat 1 year, oats 1 year, alfalfa 4 years; (5) corn 1 year, wheat 1 year, oats 1 year, winter rye 1 year, alfalfa 4 years; and (6) corn 1 year, wheat 1 year, winter rye 1 year, oats 1 year, and oats and peas (hay) 1 year.

While these rotations might not be suited to many farms on this type of soil at this time, they could be followed with profit on many, if the farm could be supplied with the necessary live stock.

The average value of the Barnes silt loam is about \$37 an acre, but some well-improved farms are held for as much as \$75 an acre.

Results of mechanical analyses of samples of the soil and subsoil of the Barnes silt loam follow:

Mechanical analyses of Barnes silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351454.....	Soil.....	0.5	2.5	2.0	10.5	16.9	58.0	14.4
351455.....	Subsoil.....	1.3	3.3	2.4	12.7	15.4	42.1	22.8

BARNES SILTY CLAY LOAM.

The soil of the Barnes silty clay loam, to a depth of 10 to 12 inches, is a black or very dark brown silty clay loam. This is underlain by dark grayish brown or drab silty clay loam or silty clay which with increasing depth gradually becomes yellowish brown mottled with gray and rusty brown. This type occurs in shallow depressions in positions much like those of the Fargo, but the soil differs from the latter in having better drainage. Around and north of Forbes there are areas of this type so large that their occurrence in depressions is not perceptible. Such areas apparently were formed by the deposition of the finest materials carried by the small streams which rise in the hills. These small streams may disappear in a wide flat of the silty clay loam from which one or more draws continue the drainage toward lower lying land, eventually joining the Elm River. There is a slight ridge of the Barnes silt loam just east of Forbes which cuts off the drainage in that direction and is largely responsible for the formation of considerable areas of this type. In this section of the county the Barnes silty clay loam merges with the silt loam type, and the two soils are difficult to separate. Spots of both heavier and lighter soil are of common occurrence in this type. Some areas of the type are heavy enough to cause difficulty in cultivation, except at times when the moisture conditions are just right.

The Barnes silty clay loam has about the same crop-producing power and the same average value as the Barnes silt loam. Wheat yields 12 to 15 bushels, oats 27 to 30 bushels, barley 18 bushels, and corn about 25 to 30 bushels per acre, under present systems of management. This type has a much greater productive capacity than these yields would indicate, and would produce better yields if the

land were cleared of weeds and crops grown in proper rotation. This soil is more difficult to cultivate than other members of the Barnes series.

Areas of this type near Forbes are valued at about \$25 and those near Kulm at \$30 or more an acre.

Results of mechanical analyses of samples of the soil and subsoil of the Barnes silty clay loam are given below:

Mechanical analyses of Barnes silty clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351404.....	Soil.....	0.2	0.6	0.6	4.3	10.3	50.2	23.6
351405.....	Subsoil.....	.2	.4	.4	2.5	10.6	53.0	22.9

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 351404, 1.22 per cent; No. 351405, 1.93 per cent.

WILLIAMS FINE SANDY LOAM.

To a depth of 10 or 12 inches the soil of the Williams fine sandy loam is a dark-brown to very dark brown, mellow or loose fine sandy loam. The subsoil is a light-brown fine sandy loam to loam, quickly becoming light gray in color or heavily spotted with grayish white with depth. The subsoil effervesces in acid, and the soil occasionally shows faint effervescence.

This type includes several variations. The greater part of it has a rolling to rough morainic topography, with an abundance of stone on the surface and with large quantities of coarse sand and fine gravel in the soil. Near the Plateau and on its east slope it is often difficult to separate this type from Rough broken land, and the boundary between the two is more or less arbitrary. Notwithstanding the loose structure and the texture of this type and its steep slopes, it is not subject to erosion, because of its heavy sod and high organic-matter content and the lack of heavy rainfall in this region. Some areas of the type have a more uniform texture and smoother topography. Such areas occur in the vicinity of large depressions, and seem to have been modified by sand blown from the beaches. In places the subsoil is not uniformly gray, and the sand is quite deep. One large area of this kind northwest of Wirsch has been classified as Valentine fine sandy loam. Northwest of White Stone Battlefield the Williams fine sandy loam approaches the texture and topography of the Williams loam.

Large fields can not be laid out on the Williams fine sandy loam because of the uneven topography, but the farmers of this section utilize a large part of the type. This land was the last in the county

to be occupied. Much of it is 15 miles from any railroad and up to six years ago there were no graded roads into the hills northwest of Forbes. There are a number of springs and small lakes scattered through this region, making it in its native state a desirable grazing country. It supports more stock than most other parts of the county. About a ton of prairie hay per acre is obtained from the hill land, and 2 tons from the depressional areas. The soil is new and produces good yields of flax, oats, wheat, and corn. Yields of 6 or 7 bushels of flaxseed, 20 to 25 bushels of corn, 10 bushels of wheat, and 22 bushels of oats per acre are obtained. This land has an average value of \$20 to \$25 an acre.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Williams fine sandy loam:

Mechanical analyses of Williams fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
3514102.....	Soil.....	2.0	7.6	5.9	31.3	10.6	34.7	7.7
3514103.....	Subsoil.....	.8	1.8	1.4	7.6	12.8	54.9	20.6

The following samples contained more than one-half of 1 per cent calcium carbonate (CaCO_3): No. 3514102, 0.72 per cent; No. 3514103, 24.45 per cent.

WILLIAMS GRAVELLY LOAM.

The Williams gravelly loam is indicated on the soil map by gravel symbols in Williams fine sandy loam color. The soil is a very dark brown, medium to coarse sandy loam containing considerable fine gravel. The subsoil is encountered at a depth of about 8 inches, and consists of a grayish-brown gravelly loam to a grayish-white, highly calcareous earthy gravel. The soil contains considerable lime carbonate. The topography usually is rolling and morainic. In places it occurs as gravelly knolls surrounded by sags of heavier and deeper soil. Some areas represent outcrops of gravel on the slopes of hills with heavier soils both above and below them. The gravel from which this type is derived is piled in rough, morainic forms, but in places shows some stratification, like large kames. (See Pl. II, fig. 1.)

The smoother areas of this type occur in German Township, while the rougher areas are scattered over the plateau around and south of Wurch. The better areas produce 5 or 6 bushels of wheat per acre, and proportionate yields of other crops, but most of the type is not suited to agriculture, being steep, stony, and droughty. It affords scant pasturage. The average value of this type is \$10 to \$15 an acre

WILLIAMS LOAM.

The soil of the Williams loam is a dark-brown to very dark brown or occasionally black, mellow loam, 12 inches deep, grading through a few inches of brown, compact loam into a grayish-white or pale yellowish gray, friable loam. The lower subsoil is pale yellow, grayish yellow or light brown, and is usually more compact than the overlying material. The subsoil contains a high percentage of lime carbonate and usually effervesces with acid nearer the surface than the corresponding type of the Barnes series. Some small, angular rock fragments are often present in the soil section. In flat areas the light-gray layer is not encountered at a depth of less than 20 inches, but on slopes and knolls the gray color is often reached near the surface, and may extend to a depth of 3 feet or more.

The Williams loam corresponds in many ways to the Barnes soils, but differs from them in its light-gray and more highly calcareous subsoil, uniformly higher elevation, and somewhat thinner soil layer. Many small spots in the Barnes soils have Williams characteristics, while small areas of soil with Barnes characteristics occur within the Williams areas. The Williams soils are very well drained, so that the gray color is not due to water-logged subsoils, but to a high content of lime and the lack of iron oxide in the subsoil. Cuts in Williams material often do not retain the light-gray color, but oxidize to a pale yellowish brown.

Most of the Williams loam occurs in one large body in the north-western corner of the county. Another large area occurs south of White Stone Battlefield, while a few small areas are found near and to the south of Wirch. The topography is gently undulating to rolling, and the type is well suited to the use of ordinary farm machinery. Some large depressions and also a few morainic hills occur in this type.

The Williams loam is as good an agricultural soil as the Barnes silt loam, and it is said that crop failures are less frequent on the plateau than on the level prairie. The type is easy to cultivate, is not drifted by the wind, and holds moisture well. Wheat yields about 14 bushels, oats 35 bushels, barley 25 bushels, corn 30 bushels, rye 18 bushels, and potatoes 85 bushels per acre. Yields of 25 to 40 bushels or more of wheat per acre are reported, and other crops do equally well in favorable years.

The average value of this type is \$32 to \$35 an acre, and well-improved and favorably located land is held for a much higher price.

Results of mechanical analyses of samples of the soil and subsoil of this type are given in the following table:

Mechanical analyses of Williams loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
351426.....	Soil.....	1.6	3.7	3.4	16.2	11.4	48.5	15.6
351427.....	Subsoil.....	1.5	4.0	2.4	10.0	9.2	49.0	23.7

EDGELEY LOAM.

The Edgeley loam has a surface soil which is dark brown to nearly black in color, loose and mellow in structure, and 8 to 12 inches deep. The subsoil is a light-brown or dull grayish brown, calcareous loam. The type has the same physical characteristics as adjoining areas of Barnes loam, but is distinguished from it by the occurrence of beds of shale rock within 5 feet of the surface and the admixture of considerable quantities of shale fragments with the glacial drift from which the soil is derived.

The Edgeley loam occurs only in a narrow belt which begins near Edgeley, in Lamoure County, and extends southward across Dickey County through range 64, continuing a long distance into South Dakota. This strip varies from about 1 mile to 2 miles in width and is regarded as the poorest land in the county. The presence of shale seems to have a bad effect on the water-holding capacity of the soil. The topography is level or gently undulating, with a few low morainic knobs and ridges breaking the monotony of the plain.

The rougher areas of the Edgeley loam are devoted largely to the production of wild hay and to pasture, while the crops common to the region are grown on the smoother areas. Only fair yields are obtained. The line of separation between the Edgeley and Barnes soils is not distinct, and along the boundary the Barnes, as mapped, is poorer and the Edgeley somewhat better than typical. The type produces from 7 to 10 bushels of wheat, 12 to 15 bushels of barley, about 16 bushels of oats, and 15 to 17 bushels of corn per acre, under present systems of management.

The type is quite variable. As previously noted the depth to the shale makes the land spotted, and fields which look quite uniform in the surface produce crops that are very uneven. Examination of these spots shows considerable variation in the soil. An examination of this type of soil on which good and poor oat crops were growing showed that there was considerable variation in the content of soluble salts or alkali in different spots.¹

¹ N. D. Agr. Expt. Sta. Special Bulletin (Food Department), vol. 11, No. 4, April, 1912, pp. 55 to 58.

Alkali in Edgeley loam soil growing good and poor oats.

Depth.	Total water-soluble alkali salts.		Sodium carbonate.	
	Good oats.	Poor oats.	Good oats.	Poor oats.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
0 to 9 inches.....	0.124	0.136	0.055	0.055
9 to 19 inches.....	.216	1.740	.122	.111
19 to 30 inches.....	.280	3.910	.180	.12

It will be noted that the soluble-salt content is much higher in the soil growing the poor oats. These soil samples were taken from the same field within 10 feet of each other; this serves to illustrate the variability of the type. The largest amount of alkali is found in the third depth, indicating that the leaching from above and the lack of drainage below have caused an accumulation at this point. There seems to be little variation in the amount of sodium carbonate present, which would indicate that other salts, such as chlorides, sulphates, etc., constitute the greater part of the alkali in the lower depths. A part of the soluble salts may be of such a nature that they are not toxic to plant growth.

The Edgeley loam mapped in the southern part of the county is slightly finer in texture than that in the northern part. The surface soil varies from a loam to a silt loam and the subsurface layer from a loam to a clay loam. The type is quite flat in topography and resembles alluvial deposits somewhat where small watercourses meander through the areas. It is better farming land than that in the northern part of the county. Almost all of it is used for the production of hay and grains.

While small areas contain considerable alkali, and certain areas of the type are no doubt lowered in crop-producing capacity by the presence of alkali, there is not enough seriously to injure the soil type as a whole, if a good system of tillage, crop rotation, and manuring were followed.

While fair crops of small grain can be produced on this type in favorable years, forage crops can be used to good advantage in the cropping system. Cultivated crops will need to be grown frequently in the rotation.

A comparison of the forage produced by corn, brome grass, alfalfa, and clover on this type of soil at the Edgeley substation is shown in the following table:

*Yields of forage crops at the Edgeley substation.**

Crop.	Number of plots.	Pounds per acre.								
		1907	1908	1909	1910	1911	1912	1913	1914	Average.
Corn.....	22	2,240	2,010	5,040	1,610	4,630	6,350	4,260	4,050	3,800
Brome grass	4	2,300	2,320	4,280	1,130	1,270	3,950	2,580	3,542	2,670
Alfalfa.....	2	.....	.....	1,000	1,000	980	3,780	1,650	3,305	1,950
Clover.....	1	.....	850	00	850	00	00	500	2,480	625

* Bul. 110, N. D. Agr. Expt. Sta., p. 179.

Corn leads in the amount of forage produced and brome grass has yielded more than alfalfa or medium red clover. The shale subsoil seems to interfere with the growth of the large root system that develops when alfalfa produces its best crop. Even though alfalfa has not yielded as much forage as corn and brome grass it has averaged a ton of hay per acre, which is a fair yield when it is remembered that alfalfa has a higher feeding value than any of the other forage crops grown in this trial. Medium-red clover has been practically a failure. Other experiments at the Edgeley substation have shown that sweet clover makes a good growth and yields well. The average yield of millet of different varieties has ranged from 1.87 tons to 2.94 tons, Early Fortune giving the smallest yield and Hungarian the largest.

The yields are an average for the five years 1903, 1904, 1905, 1908, and 1912. The rainfall during the growing period in these years was good and these yields are probably above the average for this soil type. In 1910 millet was a complete failure on this type. From these results and the experience of farmers it would seem that broom-corn millet grown for seed should prove to be a profitable crop on this type if it can be marketed to good advantage.

Sweet clover has been grown successfully at the Edgeley substation for several years, and seems to be one of the most promising legume crops for this soil type. It produces a good yield of forage, is a good pasture crop, and one of the best green-manure crops. A good stand can usually be obtained with a nurse crop, and being a biennial it fits into crop rotations without loss of time.

While alfalfa does not yield as well on this soil type as on some of the other types of the county it can be grown profitably. It will yield a good crop of hay and conditions are favorable for seed production in this region in most years. Good yields of seed and forage have been produced at the Edgeley substation. When it is grown primarily for seed the experiments at this station indicate that the best results will be obtained if it is seeded in rows and cultivated.

Where the farm is located sufficiently close to a shipping point potatoes should prove to be a profitable crop on this soil type. At the Edgeley substation the average yield of 21 varieties grown in 132 trials during the period of 1905 to 1912 was 98.9 bushels. The highest yield of any variety during the seven years the trials were carried on was 127.87 bushels per acre, and the lowest yield of any variety for this period was 79.76 bushels per acre.¹ These figures show that with good cultivation and a good variety the potato crop is profitable on this soil type if they can be marketed without too great an expense.

Rotations that would be suitable for this soil type are as follows:

(1) Corn, wheat, oats, and sweet clover; (2) potatoes, wheat, barley, and sweet clover; (3) corn, wheat, wheat, and alfalfa, 3 years; (4) corn, wheat, oats, and brome grass 3 years; and (5) corn, wheat, barley, and alfalfa 3 years.

The rotations might need to be modified to suit the conditions on individual farms, but in general they should produce fairly good yields. In the rotations where brome grass or alfalfa is grown on one field for 3 or 4 years a crop of flax might prove to be a profitable crop to seed on the sod the first year it is broken. In case this is done it should not be grown oftener than once in six or eight years on the same field.

The average value of this land is \$18 to \$20 an acre.

VALENTINE FINE SAND.

The Valentine fine sand is a brown to very dark brown, or, in places, black, loose, incoherent fine sand, about 20 inches deep, underlain by lighter brown to clean and colorless fine sand, which probably continues to great depths without change. In areas of this type the wind has blown the sand into a choppy or billowy topography, with mounds rising 2 to 6 feet above the hollows. A part of this modification by wind has taken place since the sod was first plowed in the early eighties, and wind storms still carry considerable sand. Gullies 2 or 3 feet deep have been eroded in plowed fields, and cuts in sand dunes show an old sod covered with several feet of sand.

This type is mostly confined to the southeastern corner of the county and to an area north of Glover.

Very little of the Valentine fine sand is cultivated. Fields that were once cultivated have largely been abandoned to weeds and grasses. Unbroken areas of the type support a short growth of grass, and the type is best suited for pasture land or for hay production. Alfalfa probably is the best crop for this soil, where a good stand can be obtained.

¹ N. D. Agr. Expt. Sta., Tenth Annual Report of the Edgeley Substation, 1912, p. 33.

The crop-producing capacity of this type is low and much care must be taken to prevent drifting. A fair crop of corn could be produced in some years. If the crop can be removed early and winter rye seeded and top-dressed with an application of fresh manure, drifting could be checked. After the rye crop has been removed the land could be given a light disking, but not enough to cover the stubble. If left in this condition until the following spring, oats could be seeded as a nurse crop for sweet clover. The year following the oats, the land would be in sweet clover. The sweet clover could be followed by corn or potatoes, the land being spring plowed. In this way the land will be afforded protection during the winter and only one plowing in 4 years will be required. This would make the rotation: Corn and potatoes 1 year, winter rye 1 year, oats 1 year, and sweet clover 1 year.

Durum wheat or broom-corn millet might be substituted for the oats, but if the millet is used it should be seeded lightly or it may choke out the sweet clover. Organic matter decays rapidly in sandy, loose-structured soil like this, and farm manure will need to be applied quite frequently. This should be applied where it will help to keep the soil from drifting, but it should eventually be mixed with the entire plowed layer. It should not be plowed under for small grain. In a rotation like the one outlined above a part of it could be plowed under for corn and a part used as top-dressing for the rye.

A variation of this type occurs in the Lake Dakota region, the largest areas being in secs. 11, 12, and 13 in T. 129, R. 59, bordering the county line. The soil of this variation is a brown to grayish-brown, loose, incoherent fine sand, 20 inches deep, underlain by lighter grayish brown to clean and colorless fine sand, which continues to considerable depths without change. It occurs where the wind has modified the sandy lake-bed material, so that it now has a choppy or billowy topography with mounds rising 2 to 6 feet about the hollows. Part of this modification by wind has taken place since the sod was plowed up in the early eighties, and even now the air is often filled with sand during a windstorm. Holes or "blow-outs," 2 or 3 feet deep, have been eroded in plowed fields, and cuts in sand dunes show an old sod covered with several feet of fresh sand. Very little of this variation is now cultivated. Fields that have been broken are largely abandoned to weeds and grasses. Unbroken areas of this variation are covered with a short growth of grass, and the soil should undoubtedly be devoted to pasture or hay. Alfalfa would probably be the best crop for this soil. A stand could be obtained on some of the areas if it were seeded a little late and the ground covered temporarily with a light covering

of manure or straw to check drifting while the young plants are getting a start. When a stand is obtained the field should be maintained as long as possible. After the alfalfa has once established itself it will keep the soil from drifting, but precautions should be taken to prevent soil drifting onto it from other fields.

This land is valued at \$10 to \$15 an acre.

VALENTINE FINE SANDY LOAM.

The Valentine fine sandy loam is a dark-brown, loose, friable fine sandy loam, 14 to 20 inches deep, underlain by light-brown or yellowish-brown, loose, porous fine sandy loam. The subsoil grades into a heavier and more compact loam at a depth of 30 inches to 5 feet. This soil is of quite uniform texture and usually is stone free. Large areas of the type in range 63 are derived largely from a sandy glacial drift which has been modified somewhat by both water and wind. Other areas, such as those 2 or 3 miles southeast of Fullerton, are plainly derived from sands which have been carried by strong northwest winds from sandy river bottoms or beaches and spread over the till plain. The topography usually is level or gently undulating, but is rough and slightly stony along the low Antelope moraine to the north of Monango. One large area of the type is mapped on the Missouri Plateau several miles northwest of Wirth, where the sandy deposits are quite deep and the subsoil is not light enough in color to warrant classing the material as Williams fine sandy loam. Very few areas of this type occur more than 5 miles east of the Maple River.

The Valentine fine sandy loam is less productive than soils of the Barnes series, since its sandy texture makes it less capable of withstanding drought. Its low value is due also in part to the destructive action of the wind. Like all the sandy soils, this type is infested with Russian thistle and other weeds wherever the land is not covered by a thick stand of crops. Corn, potatoes, alfalfa, and sweet clover can be grown successfully on this type, and rotations containing these crops would help to keep the land clean of weeds, and if the forage were fed and the manure returned to the soil it would increase in productivity. Special precautions should be taken to prevent the drifting of soil of the corn and potato land during the winter and land on which alfalfa has recently been seeded. A light application of manure will help to check drifting under these conditions. Stubble land would probably be less apt to drift if plowed in the spring shortly before seeding. Results at the Edgeley substation seem to indicate that if stubble land is free from weeds fairly good yields can be obtained without plowing loose soils. Plowing tends to loosen soils, and as these soils are already too loose a cropping system should be devised

which will reduce to a minimum the number of times the land is plowed. The cultivation given corn and potatoes prepares the best kind of seed bed for small grain, thus eliminating one plowing. If sweet clover is seeded with this small grain the third crop can be grown with one plowing. By the time the sweet clover field is ready to plow, the following spring, the soil will be quite compact and will contain more organic matter than at the beginning, especially if the land was manured during the winter it was in corn stubble. Oats and durum wheat are probably the best small grains to grow on this type. Winter rye might fit into some rotations to good advantage.

A considerable proportion of a farm on this type should be in forage crops. Where a good stand of alfalfa has been obtained it can be left several years. Land growing alfalfa is accumulating organic matter, and if the hay is fed and the manure is returned considerable nitrogen is added. As the organic matter helps to hold the soil together it keeps it from drifting, and as nitrogen is the element of plant food that is exhausted most rapidly on this soil type, this increase in fertility is an important asset in the growing of alfalfa.

The growing of sweet clover and hog millet for seed might prove profitable, if one is familiar with the handling and marketing of these crops.

This type has an average value of about \$25 an acre.

ROUGH BROKEN LAND.

Rough broken land includes nonagricultural land or at least land that is too rough to be farmed by the extensive methods practiced in North Dakota. Some areas are more rocky than broken. It occurs as long strips from one-eighth to one-half mile wide along the James River Valley where the hills are rather steep and gullied and include rocky knolls. A few small areas are mapped on morainic hills east of Oakes, but the largest bodies are encountered on the slope of the Missouri Plateau in the western part of the county. A rise of nearly 300 feet takes place within a distance of 1 to 3 miles, the topography being broken and hilly. A number of draws or "gulches" have been cut in this slope, but erosion is not now active, as all but the steepest bluffs are covered with thick sod. (See Pl. II, fig. 2.) On the plateau there are some morainic hill areas that are sometimes rough, rocky, and gravelly enough to be unfit for farming. However, the farmers of this region utilize many small patches of land for agriculture. Hay is cut from many small, irregularly shaped fields in the Rough broken land areas, but most of such land is used for pasture.

Where good springs or lakes are present this land sometimes sells for as much as \$20 an acre, but without these it is valued at less than \$10 an acre for pasture.

CHEMICAL COMPOSITION OF SOILS.

In the following table are given the results of complete analyses of several of the more important soils of Dickey County. The composition of the soils is expressed in pounds per acre. The samples have been taken in three depths—0 to 7 inches, representing the surface soil; 7 to 18 inches, representing the subsurface layer; and 18 to 40 inches, representing the subsoil. The weight of the surface soil has been estimated at 2,000,000 pounds, the subsurface layer at 4,000,000 pounds, and the subsoil at 6,000,000 pounds. In taking samples for analyses representative areas of each soil were selected and several borings taken to make a composite sample. Several such samples were taken of the more important types.

Chemical analyses of the more important soils of Dickey County.

UPLAND SOILS—GLACIAL AND LOESSIAL PROVINCE.

[Pounds per acre.]

Soil types.	Surface, 0 to 7 inches.			Subsurface, 7 to 18 inches.			Subsoil, 18 to 40 inches.		
	Total nitrogen.	Total phosphorus.	Lime-stone present.	Total nitrogen.	Total phosphorus.	Lime-stone present.	Total nitrogen.	Total phosphorus.	Lime-stone present.
Barnes silt loam	6,580	1,234	713	6,640	1,852	20,893	4,314	2,862	606,909
Barnes silty clay loam	7,710	1,329	333	9,080	2,034	2,592	4,527	2,214	362,973
Barnes very fine sandy loam	6,240	1,076	609	5,560	1,328	327	4,140	2,628	581,574
Williams loam	7,460	1,278	852	7,000	1,856	54,480	5,280	2,616	546,162
Williams fine sandy loam	5,100	1,014	2,410	4,400	1,516	97,156	3,960	2,148	224,730
Edgeley loam	4,550	918	388	4,240	1,346	23,808	3,744	1,941	614,112
Valentine fine sandy loam	3,240	854	4,680	3,200	1,724	290,560	2,140	2,622	770,892

TERRACE AND LAKE-BOTTOM SOILS—GLACIAL LAKE AND RIVER TERRACE PROVINCE.

Bearden fine sand	4,070	1,006	435	4,900	1,732	70,189	3,898	2,586	346,751
Bearden fine sandy loam	4,100	980	13,620	2,024	1,488	760,904	1,920	2,130	1,114,116
Bearden very fine sandy loam	6,040	1,082	735	7,040	1,944	1,471	3,900	2,574	882,578

BOTTOM-LAND SOILS—RIVER FLOOD PLAINS PROVINCE.

Lamoure clay	7,440	1,330	18,692	7,560	2,252	177,060	7,620	3,654	559,782
Lamoure silty clay	7,020	1,884	16,117	11,520	2,976	129,882	9,480	4,044	606,302

SUMMARY.

Dickey County lies along the southern boundary of North Dakota, about 70 miles west of Minnesota. It has an area of 1,142 square miles, or 730,880 acres. The county comprises three main physiographic divisions: (1) An old, sandy lake bed; (2) level, treeless prairie; and (3) a high, rolling plain—the Missouri Plateau. The lower plain, including the lake bed and the prairie, ranges in elevation from 1,300 to 1,700 feet above sea level, and the elevation of the plateau averages about 2,000 feet above sea level. On the plateau and in the Lake Dakota basin regional drainage has not been established. The remainder of the county is imperfectly drained by streams which empty into the James River.

The total population of Dickey County in 1910 was 9,839, all of which is classed as rural. The two principal towns are Ellendale, the county seat, with a population of about 1,400, and Oakes, with a population of about 1,500. The county is well supplied with transportation facilities.

The climate is characterized by long, cold winters and short, cool summers. The mean annual temperature is reported as 40° F. and the mean annual precipitation as about 23 inches. The growing season averages 122 days.

Agricultural development commenced in Dickey County about 1880. After 12 or 14 years of pioneer farming, which in many cases proved unprofitable, a definite system became established, based on the production of wheat as the money crop, with oats and corn as feed for stock.

Grain farming is now the predominant type of agriculture. Cereals, chiefly wheat, flaxseed, and hay and forage make up nearly 90 per cent of the value of all farm products, while only about 7 per cent of the total value is represented by live-stock products. Vegetables, fruit, and poultry and dairy products are of minor importance.

Of the total area of the county 81.4 per cent is reported in farms in the 1910 census, and of the farm land 69.6 per cent is reported improved. The average size of the farms is given as 546 acres. The average acreage value of farm land is given as \$33.45. About 73 per cent of the farms are operated by the owners. The adoption of scientific methods of farming is progressing rapidly.

The soils of this county are derived from glacial drift, either weathered in the position in which it was left by the ice or transported and redeposited as glacial stream terraces, as recent alluvium or as eolian deposits. The drift consists of materials derived from granite, limestone, shale, and sandstone of many formations, and varies from a thin veneer to beds 80 or 90 feet in thickness.

The soils are classed in 10 series, including 28 types, and the miscellaneous type Rough broken land.

The soils of the glacial drift region, covering the greater part of the county, are classed with the Barnes, Williams, and Edgeley series. The glacial-lake and river-terrace soils are the Sioux, Fargo, Rogers, Maple, Bearden, and Valentine series, the last being composed of wind-blown material. The first-bottom soils are classed with the Lamoure series.

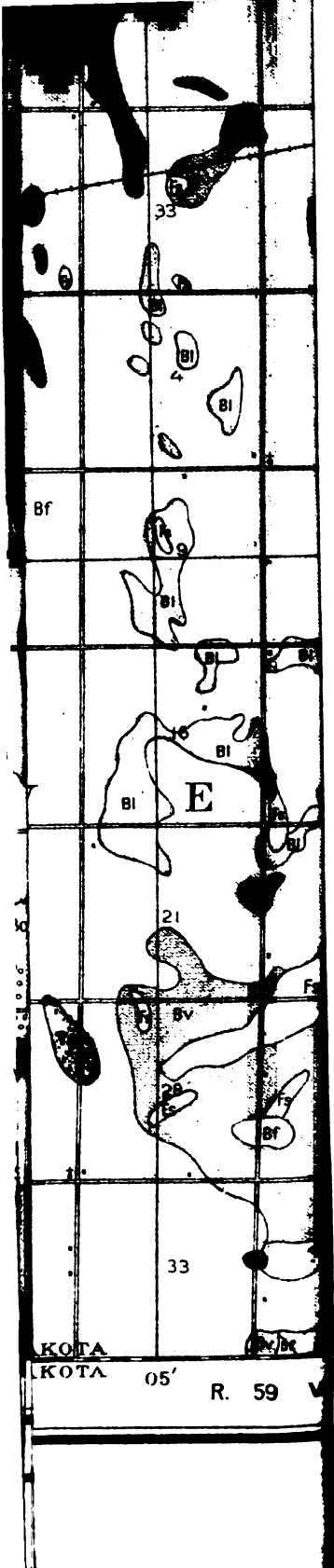
The Barnes series predominates east of the Missouri Plateau, and comprises much of the best farming land in the county. The Williams series is the glacial soil of the Missouri Plateau and is characterized by a light-gray subsoil. The Edgeley series, represented by the loam type, forms poor agricultural land, the soil being mixed with shale fragments and underlain by shale rock at shallow depths.

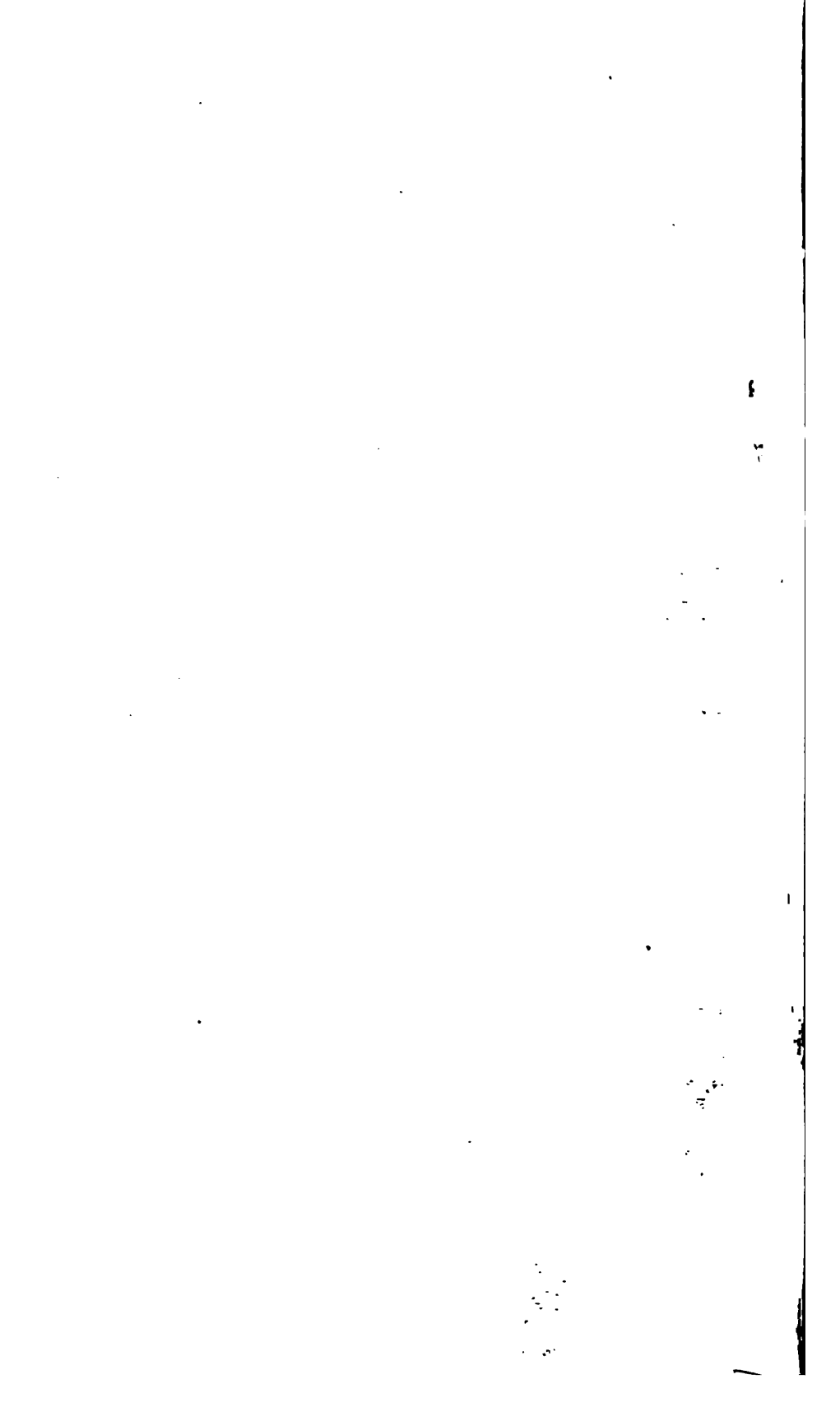
The Sioux series includes river-terrace soils underlain by gravel beds, and when these lie at shallow depths the water-holding capacity of the soil is somewhat deficient. The Fargo, Rogers, and Maple series are lake-bed soils of little present value except for the production of hay. The Rogers soils are strongly impregnated with alkali and the Maple to some extent. The Valentine series is made up of sandy wind-blown material. The Bearden series includes good, non-droughty terrace soils.

The Lamoure soils occur in the first bottoms of streams. These are deep, strong soils, not subject to drought.

Rough broken land comprises areas which are too rough and rocky for agricultural use.







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North Dakota Agricultural Experiment Station

The Milling and Baking Data for the 1915
Crop of Wheat

By Thomas Sanderson

Bulletin No. 122

Agricultural College, North Dakota

June, 1917

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* Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

	Pages
Description of tables, methods of grading and typifying and source of the samples	61 and 78
Tables I to XXVIII comprising data for the four types, Bluestem, Fife, Velvet Chaff and Marquis of the Hard Red Spring Class.....	62-72
Tables XXIX to XLVI showing data from the other types of wheat tested	72-77
Remarks and a general summing up of Tables I to XXVIII and the introduction of Table XLVII to show conclusions	79 and 80
Table XLVIII showing average results taken from Tables I to XXVIII by types and grades	80 and 81
A basis of market value for wheat and mill products	82
Discussion of Table XLVIII showing application of the test weight per bushel to determine grade	82 and 83
The proper use of the test weight per bushel and its growth into our present system of grading	83-85
The milling industry as a factor in the growth of our present system of grading and the application of the test weight per bushel establishing grade compared with the value of the mill product.....	85-88
The value of the different types of wheat by grades, the percentage of each type and the average of the four types as shown in Table XLVIII based on No. 1' Bluestem as standard, also the percentage of the different grades and the value of mill products based on this percentage	89-91
Some illustrations of the working of the system of grading	91-93
Names and addresses of the producers of the samples and the laboratory number	93 and 94

FOREWORD.

One of the most important questions that the producer has to deal with is that of finding a good market for his surplus product, but of no less importance is the question of properly determining the true grade or value of the product, and, in the case of wheat, the determination of the proper grade is of great moment for it may mean profit or loss, according to whether the product is classed as No. 1 or No. 4 in grade.

In order to have a correct knowledge of the value of wheat we must first have made a careful study of wheat as produced and placed upon the market in any given locality, covering a considerable period of time, as well as of all varieties and conditions as to the effect of smut, blight, frosting, bin-burning, excessive dampness, foreign ingredients, separable and inseparable, as well as the value of the final products produced from the wheat.

Previous bulletins and reports contain data for different years since 1907, and in the present bulletin Mr. Sanderson presents valuable original data for the North Dakota wheat crop of 1915. This material is presented as prepared in June, 1916, and as offering a further basis for discussion and study of the question now so prominently before the wheat growers of North Dakota. The discussion by Mr. Sanderson of the miller's problems and of the relative value of the different grades of wheat will prove enlightening and worth thoughtful consideration by those who have to do with the settling of the farmers' perplexing problem as to the true value of any particular lot of wheat, and at the same time will furnish the millers with useful knowledge as to the kind of product that may be had from the individual sample. I therefore recommend the early publication of this material in accordance with the provisions of the Statute authorizing wheat studies.

E. F. LADD.

THE MILLING AND BAKING DATA FOR THE 1915 CROP OF WHEAT

By Thomas Sanderson

The data from all of the samples of wheat tested by the station for the crop year 1915 are submitted. The figures in the tables that follow were taken from the original report on the individual samples.

The number of tables covering this data could be reduced by tabulating by classes of wheat, but as some of the classes are composed of several types, the tabulating has been done by type and by grade within each type. Since the work was done in the same way last year including all the data accumulated since the starting of this work at the station, it was thought best to continue in the same way. The factors reported in these tables are the more important ones for a general study of quality and value.

Tables I to XXVIII, inclusive, represent the wheat types by grades (as designated by Minnesota Inspection Department) contained in what is called the Hard Red Spring Class. Tables XXIX and XXX, Hard Red Winter Class. Tables XXXI to XXXVII, Durum Class. Tables XXXVIII and XXXIX unclassified samples. Tables XL to XLVI Semi Hard Red Spring Wheat Class. On the Minnesota market this last type would almost invariably have to be sold on sample or be classed as Western Red, and in either case would not bring the market price of the Hard Red Spring Class.

For a fair comparative study of value between the types and grades within the type, and the classes, it would be necessary to have each grade and type within the class represented by the same number of samples, and these samples taken from the same general locality, which is not the case with this data. These samples in a general way, may be compared with the conditions existing at any of our terminal markets. The wheat going to any of our terminal markets is graded and classified according to established rules regardless of locality as far as the State of North Dakota is concerned. These samples have been received from the different localities in the state, and they have been graded according to the established rules employed by the Minnesota Grain Inspection Department. A larger percentage of the wheat received here is true to type than is the case with the wheat going to the markets. The samples coming here from the Central Station the Sub-Stations and the Demonstration Farms are fairly true to type while those from individual farmers are often badly mixed and hard to typify.

The rule of the inspection department seems to be to use the Bluestem type as a standard with no distinction between that and Fife and Marquis, but to make a difference in price between the Bluestem and Velvet Chaff of $\frac{1}{2}$ to 4 cents per bushel. The grading rules are also more stringently applied to this type, making the discrimination against it about 2 to 8 cents per bushel.

In a study of the data for the 1915 crop year, I find only two of the types of the Hard Red Spring Class to have all of the grades

TABLE III—NO. 2 BLUESTEM

[illegible]

TABLE IV—NO. 3° BLUESTEM

2473	53.5	57.5	1.71	67.93	15.06	13.55	3.96	58.5	2285	75.	88.5
2479	53.5	57.	1.98	67.02	18.45	12.73	1.80	58.2	2430	96.	94.
2485	53.5	58.	2.50	67.74	13.13	13.13	3.00	59.1	2325	93.	95.
2487	53.	57.	2.60	67.94	16.53	14.40	2.13	59.4	2325	86.	89.5
2489	54.	57.	2.61	70.01	14.93	12.86	2.20	58.8	2380	83.5	89.5
2490	53.	57.5	2.41	68.68	16.12	13.60	2.60	59.1	2360	88.	90.
2491	54.	58.	1.50	69.68	14.26	12.93	3.13	59.4	2350	86.	91.
2507	56.	60.5	1.72	70.13	15.87	13.13	.87	57.6	2275	93.5	98.5
2518	51.5	58.	3.77	69.55	15.06	14.26	1.13	58.5	2185	90.	93.
2519	55.	60.	3.00	71.29	13.53	15.05	47.*	58.8	2210	92.	94.
2521	54.	58.5	1.90	69.14	13.06	14.13	3.67	59.5	2245	86.	93.
2738	54.	58.	2.32	69.15	13.67	12.94	3.54	58.9	2390	94.5	95.
2774	56.	60.	6.34	71.02	13.46	11.56	3.66	58.3	2355	94.	90.5
2776	54.5	61.	4.34	69.15	12.73	14.26	3.86	58.3	2175	89.5	84.5
2814	53.	57.	5.07	67.39	14.17	13.20	5.24	57.6	2080	78.	89.5
2832	55.5	59.00	2.94	67.94	14.00	14.12	3.94	58.2	2680	98.	98.5
2852	55.5	59.5	7.05	83.73	16.74	16.26	3.27	61.2	2675	99.	95.

*** Gain in milling.**

FIFE WHEAT BY GRADES, 1915 CROP.
TABLE VII—NO. 1 HARD FIFE

	47.5	52.5	7.84	65.08	14.47	17.47	3.00	59.1	2050	60.	80.
2476	47.5	52.5	7.84	65.08	14.47	17.47	3.00	59.1	2050	60.	80.
2478	48.5	53.	4.01	65.30	16.86	16.18	1.00	58.8	2285	78.	88.
2482	48.5	54.	4.59	65.74	16.80	15.13	2.33	58.2	2405	87.	90.
2484	50.	56.	3.75	67.00	15.48	14.54	3.00	58.8	2270	88.	93.
2780	47.5	52.5	11.15	66.40	14.87	16.06	2.67	60.3	2275	88.	92.
2827	41.	45.5	11.30	52.65	21.35	20.46	1.66	62.4	1540	55.	60.
2881	47.	51.	2.55	67.22	13.40	15.45	3.93	62.6	2280	83.	89.
2890	46.5	51.5	5.32	67.28	10.33	18.46	5.98	65.9	2570	87.	95.
2935	47.	51.	4.12	66.49	13.20	18.98	1.33	61.8	2570	95.	97.
Average	47.05	51.77	6.07	64.81	15.19	17.19	2.81	60.88	2246	80.11	87.
Maximum	50.	55.	11.30	67.28	21.35	24.46	5.93	65.90	2570	95.	97.
Minimum	41.	45.50	2.55	52.65	10.33	14.54	1.33	58.20	1540	55.	60.
Market value per bushel											
Gross gain per cent								\$.8614			
								\$1.2830			
								49.1			

[illegible]

TABLE VIII—NO. 1° FIVE

[illegible]

* Gain in milling.

VELVET CHAFF WHEAT BY GRADES, 1915 CBOP.
TABLE XIII—NO. 1 HARD.—VELVET CHAFF

2671	52.5	57.	9.70	66.37	14.97	13.25	5.41	60.	2145	65.	93.5
2781	46.	52.	7.35	65.20	16.20	18.40	.20	61.2	2090	87.	87.
2783	46.	51.	8.41	64.14	15.89	18.27	2.20	59.1	2820	93.	90.
2784	48.	52.	6.02	63.16	15.86	17.98	3.00	59.7	2665	98.	96.
Average	48.12	53.	6.61	64.72	15.60	16.98	2.70	60.	2380	84.50	91.62
Maximum	52.50	57.	9.70	66.37	16.20	18.40	5.41	61.20	2665	93.	96.
Minimum	46.00	51.	3.41	63.16	14.97	13.25	.20	59.10	2090	65.	87.
Market value per bushel											
Gross gain per cent										\$.8614	\$1.2859 49.2

2600	61.5	64.	2.29	73.21	10.07	14.93	1.79	63.2	2275	98.5	91.
2908	62.	65.	1.33	73.44	13.13	13.39	.04	62.4	2250	96.	92.5
2920	59.5	62.	3.09	73.40	11.20	14.40	1.00	63.2	2255	94.	86.5
2950	61.	63.5	.77	72.86	12.34	11.40	3.40	62.1	2415	93.	92.
Average	61.	63.62	1.87	73.23	11.98	13.53	1.56	62.72	2299	95.38	90.50
Maximum	62.	65.	3.09	73.44	13.13	14.93	3.40	63.20	2415	98.50	92.50
Minimum	59.5	62.	.77	72.86	10.07	11.40	.04	62.10	2250	93.	86.50
Market value per bushel											
Gross gain per cent										\$1.0342	\$1.3581 31.3

TABLE XIV—NO. 1—VELVET CHAFF

2689	59.	64.5	4.44	70.74	11.65	15.65	1.96	58.8	2000	92.	91.
2833	59.	61.5	2.60	61.24	17.57	13.87	7.52	58.8	2465	98.5	95.
Average	59.	63.	3.52	69.99	14.61	14.96	4.74	58.8	2233	95.25	93.
Maximum	59.	64.50	4.44	70.74	17.57	15.65	7.52	58.8	2465	98.50	96.
Minimum	59.	61.50	2.60	61.24	11.65	13.87	1.96	58.8	2000	92.00	91.
Market value per bushel											
Gross gain per cent										\$1.0292	\$1.2747 28.8

TABLE XV—NO. 2—VELVET CHAFF

2767	57.5	60.	2.91	63.33	18.65	12.25	5.77	57.4	2275	97.	92.5
2862	57.5	61.	1.72	71.34	8.28	16.32	4.06	61.5	2190	82.	89.
2875	57.5	60.	4.12	69.87	9.14	18.66	2.13	62.4	2510	95.	96.5
2884	57.5	60.	.61	69.80	12.20	15.53	2.47	60.3	2180	82.	88.
2930	56.	59.	4.16	69.07	16.93	16.93	2.93*	62.1	2195	95.5	89.

* Gain in milling.

TABLE XIX—NO. 2°—MARQUIS

[illegible]

TABLE XX—NO. 3°—MARQUIS

[illegible]

* Gain in milling.

2931	53.	56.	6.60	11.20	22.60	.40*	64.1	2525	94.5	95.5
2940	53.5	57.	2.31	67.69	17.59	2.60	58.8	3125	101.	100.
Average	53.25	56.50	4.45	67.15	11.66	20.09	61.45	2625	97.75	\$1.5046
Maximum	58.50	57.	6.60	67.69	12.12	22.60	64.10	3125	101.	\$2.1948
Minimum	53.	56.	2.31	66.60	11.20	17.59	58.80	2525	94.5	95.50
Market value per bushel										\$.9027
Gross gain per cent										\$1.8165
										45.8

PRELUDE WHEAT BY GRADES, 1915 CROP.

TABLE XXV—NO. 1 HARD PRELUDE

2902	62.	64.	1.88	75.99	7.81	15.33	.87	62.1	2530	87.5
2922	60.5	62.	3.80	72.42	12.39	16.86	.67*	62.9	2685	97.5
2952	63.	64.	.86	77.86	9.88	12.06	.40	62.9	2360	95.
Average	61.83	63.38	2.15	75.35	10.03	14.42	.20	62.63	2525	96.63
Maximum	63.	64.	3.90	77.86	12.39	15.86	.87	62.90	2685	97.50
Minimum	60.50	62.	.86	72.42	7.81	12.06	.67*	62.10	2360	95.00
Market value per bushel										\$1.7237
Gross gain per cent										\$1.0342
										\$1.3969
										35.1

TABLE XXVI—NO. 1* PRELUDE

2864	58.	61.	2.34	73.34	10.40	14.93	1.33	61.2	2780	91.	95.5
2877	58.	60.5	3.09	72.93	9.14	16.85	1.08	62.1	2220	88.	91.
2886	59.	61.5	1.54	72.53	9.81	14.66	3.00	61.5	2300	87.	88.
2941	58.5	60.5	2.95	72.53	11.13	13.87	2.47	62.4	2900	96.	96.
Average	58.38	60.62	2.48	72.83	10.12	15.08	1.97	61.80	2550	90.50	92.62
Maximum	59.	61.50	3.09	73.34	11.13	16.85	3.00	62.40	2900	96.	96.
Minimum	58.	60.50	1.54	72.53	9.14	13.87	1.08	61.20	2220	87.	88.
Market value per bushel											\$1.0292
Gross gain per cent											\$1.3614
											32.2

AUSTRALIAN WHEAT, 1915 CROP.

TABLE XXVII—NO. 1* AUSTRALIAN

2910	63.5	65.	2.35	76.21	9.00	14.59	.20	63.5	1880	95.	92.5
Market value per bushel											\$1.7154
Gross gain per cent											\$1.0292
											\$2.3455
											\$1.4073
											36.7

* Gain in milling.

DEFIANCE WHEAT BY GRADES, 1915 CROP.

TABLE XXVIII—NO. 1st DEFIANCE

Lab. No.	Weight per bushel		Loss in cleaning	Total flour		Bran	Shorts		Loss in milling	Water absorbed	Volume loaf	Score		Market value of 100 lb wheat	Market value of 100 lb mill products
	Pounds	After cleaning		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	C. C.	Color	Texture		
2911	59.	61.5	.29	70.80	14.27	.....	13.53	1.40	.....	60.3	2210	96.	90.	\$1.7154	\$2.2208
Market value per bushel	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	\$1.3824	.....
Gross gain per cent	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29.4

HARD RED WINTER WHEAT BY GRADES, 1915 CROP.

TABLE XXIX—NO. 1 HARD RED WINTER

2868	60.	63.	1.71	72.41	12.80	12.80	13.06	1.73	.....	62.6	2280	94.	88.	.....	.....
2888	61.5	64.5	.63	71.61	13.00	13.00	12.46	2.93	.....	59.1	2640	94.	96.	.....	.....
Average	60.75	63.75	1.17	72.01	12.90	12.90	12.76	2.33	.....	60.85	2460	94.	92.	\$1.7154	\$2.2387
Maximum	61.50	64.50	1.71	72.41	13.00	13.00	13.06	2.93	.....	62.60	2640	94.	96.	.....	.....
Minimum	60.	63.00	.63	71.61	12.80	12.80	12.46	1.73	.....	59.10	2280	94.	88.	\$1.0292	\$1.3482
Market value per bushel	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.5
Gross gain per cent	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE XXX—NO. 2 HARD RED WINTER

2867	58.	62.5	1.67	71.67	12.00	12.00	13.00	3.33	.....	62.4	2285	88.5	88.5	.....	.....
2889	58.	61.5	3.86	70.80	11.50	11.50	14.50	3.20	.....	63.8	2150	88.	92.	.....	.....
Average	58.	62.00	2.76	71.24	11.75	11.75	13.75	3.26	.....	63.10	2217	88.25	90.25	\$1.6429	\$2.2278
Maximum	58.	62.50	3.86	71.67	12.00	12.00	14.50	3.33	.....	63.80	2285	88.50	92.	.....	.....
Minimum	58.	61.50	1.67	70.80	11.50	11.50	13.00	3.26	.....	62.4	2150	88.00	88.50	\$.9857	\$1.3366
Market value per bushel	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	35.5
Gross gain per cent	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

DURUM WHEAT BY GRADES, 1915 CROP.

TABLE XXXI—NO. 1 DURUM

2611	60.	62.5	4.12	69.33	9.14	19.07	2.46	60.3	1955	88.	92.	.....	.....	.....	.....
2674	62.5	64.	3.16	71.48	8.40	18.32	1.80	58.2	1700	96.	90.	.....	.....	.....	.....
2675	62.5	65.5	1.76	72.55	9.00	16.52	1.93	57.7	1620	93.	90.	.....	.....	.....	.....

TABLE XXXII—NO. 2 DURUM

	60.5	63.	3.15	70.90	11.58	13.47	3.08	54.7	1900	95.	90.
2882	60.5	62.5	1.53	67.71	12.04	18.23	2.02	60.6	1920	90.	92.5
2886	59.5	62.	3.41	71.00	7.74	20.93	.33	80.6	2205	89.	89.
2869	60.	62.5	2.50	72.47	7.80	18.93	1.20	62.9	2045	94.5	93.
2893	63.	64.5	1.88	74.49	10.13	14.58	.80	62.9	2055	94.	91.5
2894	63.	64.5	1.81	75.35	7.00	16.45	1.20	60.6	1750	96.	89.
2905	63.	65.	1.81	73.94	11.46	14.13	.47	63.2	1900	97.	92.
2912	63.	64.	2.96	75.60	10.40	14.47	.47*	60.9	2015	95.	92.5
2915	60.5	62.5	2.82	72.21	11.19	18.00	1.40*	65.3	1905	89.	92.5
2923	60.5	63.	4.43	75.48	9.14	17.18	1.80*	63.8	2230	94.	92.5
2924	60.	63.	3.31	74.69	10.66	16.05	1.40*	62.1	1960	95.	92.5
2943	61.5	63.5	2.74	72.65	10.73	16.00	.52	62.4	2190	90.	92.5
2944	62.5	64.	3.48	76.40	7.00	15.87	.76	61.5	2100	93.	93.
Average	61.50	63.50	2.74	72.89	9.59	16.76	.76	61.25	1967	93.03	91.5
Maximum	63.00	65.50	4.43	76.40	12.04	20.93	3.06	66.60	2230	97.	93.
Minimum	59.50	62.00	.78	67.71	7.00	13.47	1.30*	54.70	1620	88.	89.
Market value per bushel											
Gross gain per cent											
2814	61.	64.	5.56	71.00	9.34	19.06	.60	58.6	1900	90.	92.
2735	55.	61.5	4.15	68.22	14.98	12.00	4.80	55.6	2100	87.	93.
2736	58.5	62.	2.46	72.28	12.52	11.40	3.80	55.3	2150	88.5	92.
2737	59.	61.5	1.72	71.02	11.46	14.86	2.96	55.9	1910	88.	87.5
2759	60.	62.	3.79	68.61	10.80	15.46	5.13	56.2	1815	91.5	91.
2764	59.5	62.	2.46	68.80	12.40	15.47	3.33	58.	2045	93.	92.5
2786	58.	60.	5.29	73.17	9.34	15.32	2.17	62.6	2460	92.	95.
2787	57.5	61.	2.21	68.81	9.01	19.58	2.60	62.4	2395	94.	96.
2804	57.	60.	6.92	69.01	12.73	14.33	3.93	55.9	2250	95.	97.5
2805	60.5	63.	3.86	69.88	12.88	13.73	3.53	57.2	1950	90.	88.5
2806	59.	62.	5.49	70.75	11.68	14.66	2.93	58.9	1885	91.5	87.5
2807	60.5	64.	4.17	68.82	11.92	14.53	5.33	58.9	1980	92.5	88.5
2830	57.5	61.5	4.13	68.61	14.15	17.38	1.11	58.8	2070	93.5	95.
2841	59.	62.5	1.99	68.62	14.17	17.98	2.05	59.1	2160	91.	91.
2851	60.	62.5	1.55	66.68	14.13	16.28	2.06	59.1	1920	91.	85.
2856	57.5	60.5	1.70	66.66	9.54	21.00	3.00	59.1	2350	80.	94.
2866	57.	59.5	1.85	70.68	10.53	18.72	.37	57.6	2385	93.	94.
2833	58.	60.	.36	67.80	8.14	20.80	3.26	62.4	2570	93.	94.5
2934	57.5	60.	.86	66.64	8.29	22.27	2.80	61.2	2575	97.	96.
Average	58.52	61.47	3.18	69.04	11.44	16.55	2.97	58.72	2203	90.84	91.61
Maximum	60.50	64.00	6.92	73.17	14.98	22.27	5.38	62.60	2575	97.	97.50
Minimum	55.00	59.50	.36	66.62	8.14	11.40	.37	55.60	1815	80.	85.00
Market value per bushel											
Gross gain per cent											
2814	61.	64.	5.56	71.00	9.34	19.06	.60	58.6	1900	90.	92.
2735	55.	61.5	4.15	68.22	14.98	12.00	4.80	55.6	2100	87.	93.
2736	58.5	62.	2.46	72.28	12.52	11.40	3.80	55.3	2150	88.5	92.
2737	59.	61.5	1.72	71.02	11.46	14.86	2.96	55.9	1910	88.	87.5
2759	60.	62.	3.79	68.61	10.80	15.46	5.13	56.2	1815	91.5	91.
2764	59.5	62.	2.46	68.80	12.40	15.47	3.33	58.	2045	93.	92.5
2786	58.	60.	5.29	73.17	9.34	15.32	2.17	62.6	2460	92.	95.
2787	57.5	61.	2.21	68.81	9.01	19.58	2.60	62.4	2395	94.	96.
2804	57.	60.	6.92	69.01	12.73	14.33	3.93	55.9	2250	95.	97.5
2805	60.5	63.	3.86	69.88	12.88	13.73	3.53	57.2	1950	90.	88.5
2806	59.	62.	5.49	70.75	11.68	14.66	2.93	58.9	1885	91.5	87.5
2807	60.5	64.	4.17	68.82	11.92	14.53	5.33	58.9	1980	92.5	88.5
2830	57.5	61.5	4.13	68.61	14.15	17.38	1.11	58.8	2070	93.5	95.
2841	59.	62.5	1.99	68.62	14.17	17.98	2.05	59.1	2160	91.	91.
2851	60.	62.5	1.55	66.68	14.13	16.28	2.06	59.1	1920	91.	85.
2856	57.5	60.5	1.70	66.66	9.54	21.00	3.00	59.1	2350	80.	94.
2866	57.	59.5	1.85	70.68	10.53	18.72	.37	57.6	2385	93.	94.
2833	58.	60.	.36	67.80	8.14	20.80	3.26	62.4	2570	93.	94.5
2934	57.5	60.	.86	66.64	8.29	22.27	2.80	61.2	2575	97.	96.
Average	58.52	61.47	3.18	69.04	11.44	16.55	2.97	58.72	2203	90.84	91.61
Maximum	60.50	64.00	6.92	73.17	14.98	22.27	5.38	62.60	2575	97.	97.50
Minimum	55.00	59.50	.36	66.62	8.14	11.40	.37	55.60	1815	80.	85.00
Market value per bushel											
Gross gain per cent											
2814	61.	64.	5.56	71.00	9.34	19.06	.60	58.6	1900	90.	92.
2735	55.	61.5	4.15	68.22	14.98	12.00	4.80	55.6	2100	87.	93.
2736	58.5	62.	2.46	72.28	12.52	11.40	3.80	55.3	2150	88.5	92.
2737	59.	61.5	1.72	71.02	11.46	14.86	2.96	55.9	1910	88.	87.5
2759	60.	62.	3.79	68.61	10.80	15.46	5.13	56.2	1815	91.5	91.
2764	59.5	62.	2.46	68.80	12.40	15.47	3.33	58.	2045	93.	92.5
2786	58.	60.	5.29	73.17	9.34	15.32	2.17	62.6	2460	92.	95.
2787	57.5	61.	2.21	68.81	9.01	19.58	2.60	62.4	2395	94.	96.
2804	57.	60.	6.92	69.01	12.73	14.33	3.93	55.9	2250	95.	97.5
2805	60.5	63.	3.86	69.88	12.88	13.73	3.53	57.2	1950	90.	88.5
2806	59.	62.	5.49	70.75	11.68	14.66	2.93	58.9	1885	91.5	87.5
2807	60.5	64.	4.17	68.82	11.92	14.53	5.33	58.9	1980	92.5	88.5
2830	57.5	61.5	4.13	68.61	14.15	17.38	1.11	58.8	2070	93.5	95.
2841	59.	62.5	1.99	68.62	14.17	17.98	2.05	59.1	2160	91.	91.
2851	60.	62.5	1.55	66.68	14.13	16.28	2.06	59.1	1920	91.	85.
2856	57.5	60.5	1.70	66.66	9.54	21.00	3.00	59.1	2350	80.	94.
2866	57.	59.5	1.85	70.68	10.53	18.72	.37	57.6	2385	93.	94.
2833	58.	60.	.36	67.80	8.14	20.80	3.26	62.4	2570	93.	94.5
2934	57.5	60.	.86	66.64	8.29	22.27	2.80	61.2	2575	97.	96.
Average	58.52	61.47	3.18	69.04	11.44	16.55	2.97	58.72	2203	90.84	91.61
Maximum	60.50	64.00	6.92	73.17	14.98	22.27	5.38	62.60	2575	97.	97.50
Minimum	55.00	59.50	.36	66.62	8.14	11.40	.37	55.60	1815	80.	85.00
Market value per bushel											
Gross gain per cent											
2814	61.	64.	5.56	71.00	9.34	19.06	.60	58.6	1900	90.	92.
2735	55.	61.5	4.15	68.22	14.98	12.00	4.80	55.6	2100	87.	93.
2736	58.5	62.	2.46	72.28	12.52	11.40	3.80	55.3	2150	88.5	92.
2737	59.	61.5	1.72	71.02	11.46	14.86	2.96	55.9	1910	88.	87.5
2759	60.	62.	3.79	68.61	10.80	15.46	5.13	56.2	1815	91.5	91.
2764	59.5	62.	2.46	68.80	12.40	15.47	3.33	58.	2045	93.	92.5
2786	58.	60.	5.29	73.17	9.34	15.32	2.17	62.6	2460	92.	95.
2787	57.5	61.	2.21	68.81	9.01	19.58	2.60	62.4	2395	94.	96.
2804	57.	60.	6.92	69.01	12.73	14.33	3.93	55.9	2250	95.	97.5
2805	60.5	63.	3.86	69.88	12.88	13.73	3.53	57.2	1950	90.	88.5
2806	59.	62.	5.49	70.75	11.68	14.66	2.93	58.9	1885	91.5	87.5
2807	60.5	64.	4.17	68.82	11.92	14.53	5.33	58.9	1980	92.5	88.5
2830	57.5	61.5	4.13	68.61	14.15	17.38	1.11	58.8	2070	93.5	95.
2841	59.	62.5	1.99	68.62	14.17	17.98	2.05	59.1	2160	91.	91.
2851	60.	62.5	1.55	66.68	14.13	16.28	2.06	59.1	1920	91.	85.
2856	57.5	60.5	1.70	66.66	9.54	21.00	3.00	59.1	2350	80.	94.
2866	57.	59.5	1.85	70.68	10.53	18.72	.37	57.6	2385	93.	94.
2833	58.	60.	.36	67.80	8.14	20.80	3.26	62.4	2570	93.	94.5
2934	57.5	60.	.86	66.64	8.29	22.27	2.80	61.2	2575	97.	96.
Average	58.52	61.47	3.18	69.04	11.44	16.55	2.97	58.72	2203	90.84	91.61
Maximum	60.50	64.00	6.92	73.17	14.98	22.27	5.38	62.60	2575	97.	97.50
Minimum	55.00	59.50	.36	66.62	8.14	11.40	.37	55.60	1815	80.	85.00
Market value per bushel											
Gross gain per cent											
2814	61.	64.	5.56	71.00							

TABLE XXXIII—NO. 3 DURUM

Lab. No.	Weight per bushel Before After cleaning cleaning		Loss in cleaning		Total flour		Bran		Shorts		Loss in milling		Water absorbed		Volume loaf	Score			Market value of 100 lb wheat	Market value of 100 lb mill products	
	Pounds	Pounds	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Color		Texture					
2710	57.	61.5	8.25	64.22	11.86	19.26	4.86	59.7	1660	66	80.										
2779	56.	61.5	12.46	68.74	11.66	15.40	4.20	56.5	2050	91.5	91.										
2853	53.5	58.5	4.78	60.67	16.51	21.73	1.99	64.1	2010	93.	93.5										
2879	55.5	58.	5.89	70.82	7.67	19.45	2.06	63.3	2555	94.5	96.										
2880	56.	58.	1.07	68.09	7.14	21.04	3.73	60.9	1990	88.	90.										
2891	54.5	57.	1.16	67.96	10.80	17.71	3.53	61.8	2060	85.5	91.5										
Average	55.41	59.08	4.43	66.75	10.94	19.10	3.21	61.39	2054	86.42	90.33										
Maximum	57.00	61.50	12.46	70.82	16.51	21.73	4.66	65.30	2555	94.50	96.										
Minimum	53.50	57.00	.89	60.67	7.14	15.40	1.99	56.50	1660	66.00	80.										
Market value per bushel																					
Gross gain per cent																				\$.8854	\$1.2994 46.7

TABLE XXXIV—REJECTED DURUM

[illegible]

RED DURUM WHEAT BY GRADES, 1915 CROP.

TABLE XXV—NO. 1—RED DURUM

2015	60.	63.	6.98	70.00	9.00	19.00	2.00	55.1	1390	80.	80.	\$1,3246	\$2,2521
Market value per bushel													
Gross gain per cent													
\$.9747													
38.6													

TABLE XXXVI—NO. 4—RED DURUM

2008	52	60	66.71	77.73	16.05	.49*	62.4	1705	90	87.5	\$1.4157†	\$2.2098
Market value per bushel												
Gross gain per cent											\$.8494	\$1.3259

MISCELLANEOUS WHEATS BY GRADES, 1915 CROP.

TABLE XXXVII—NO. 1—TACANROG DURUM

2913	62.5	64.	2.06	74.35	9.60	15.32	.73	61.2	1505	95.	94.	\$1.6246	\$2.3061
Market value per bushel												\$.9747	\$1.3836
Gross gain per cent													41.9

TABLE XXXVIII—NO. 1—EGYPTIAN

2963	62.	62.	Not	74.93	6.41	19.82	1.16*	60.3	1585	88.5	75.	\$1.7154	\$2.3290
Market value per bushel												\$1.0292	\$1.3974
Gross gain per cent													35.7

TABLE XXXIX—NO. 3—ALASKA

2968	59.	60.	1.38	75.53	6.00	18.20	.27	60.3	1960	91.	87.	\$1.5671	\$2.3327
Gross gain per bushel												\$.9402	\$1.3896
Market value per bushel													48.8

SEMI HARD SPRING WHEAT BY GRADES, 1915 CROP.

TABLE XL—NO. 1—MANCHURIA †

2903	60.	63.	2.70	89.66	12.47	14.40	3.47	57.9	1805	89.	80.		
2932	58.	60.5	3.58	66.03	13.79	18.71	1.47	55.	1970	90.	90.		
2953	60.5	63.	2.55	69.76	11.46	15.42	2.86	60.6	1825	84.	79.		
Average	59.50	62.16	2.94	68.48	12.58	16.34	2.60	57.83	1867	87.66	83.	\$1.7154	\$2.1889
Maximum	60.50	63.	3.58	69.76	13.79	18.71	3.47	60.6	1970	90.	90.		
Minimum	58.00	60.50	2.55	66.03	11.46	14.40	1.47	55.	1805	84.	79.		
Market value per bushel												\$1.0292	\$1.3133
Gross gain per cent													27.6

TABLE XLI—NO. 2—MANCHURIA †

2865	57.	61.	1.07	67.63	10.06	18.25	4.06	60.6	1870	80.	80.	\$1.6429	\$2.1517
Market value per bushel												\$.9557	\$1.3910
Gross gain per cent													30.9

* Gain in milling.

† Estimated, market value not quoted.

TABLE XLII—NO. 3 MANCHURIA ‡

Lab. No.	Weight per bushel Before cleaning		Loss in cleaning Per cent	Total flour Per cent	Bran Per cent	Shorts Per cent	Loss in milling Per cent	Water absorbed Per cent	Score		Market value of 100 lb mill products
2887	Pounds	55.5	58.5	1.82	63.48	11.27	19.32	5.93	60.	74.	\$1.5671
Market value per bushel											\$2.0482
Gross gain per cent											\$1.2391
											\$1.9402
											\$1.8

TABLE XLIIA—NO. 4 MANCHURIA ‡

2878	52.5	56.	4.17	65.35	11.68	19.66	3.33	60.3	1910	85.	82.
2942	52.	56.5	1.76	62.82	16.45	16.86	3.87	57.1	2150	80.	85.
Average	52.25	56.25	2.96	64.09	14.05	18.26	3.60	58.70	2080	82.50	83.50
Maximum	52.50	56.50	4.17	65.35	16.45	19.66	3.87	60.30	2150	85.	85.
Minimum	52.	56.00	1.76	62.82	11.66	16.86	3.33	57.10	1910	80.	82.
Market value per bushel											\$1.9027
Gross gain per cent											\$1.2617
											39.7

TABLE XLIII—NO. 1 GHIRKA ‡

2898	60.5	63.	.34	70.73	10.40	16.80	2.07	62.1	2225	99.	98.5
2906	61.	64.	...	69.49	16.66	13.32	.53	61.5	2245	99.	96.
2918	59.	62.	2.82	69.88	13.07	15.85	1.20	62.4	2165	93.	94.
2948	59.	62.	2.82	70.09	13.66	13.32	2.73	62.9	2040	92.	85.
Average	59.87	62.75	1.92	70.05	13.60	14.82	1.93	62.22	2169	95.75	92.87
Maximum	61.00	64.	2.82	70.73	16.66	16.80	2.73	62.90	2245	99.	96.
Minimum	59.	62.	.34	69.49	10.40	13.32	.53	61.50	2040	92.	85.
Market value per bushel											\$1.7154
Gross gain per cent											\$1.0292
											\$1.8204
											39.2

TABLE XLIV—NO. 2 GHIRKA ‡

2873	57.	60.5	2.87	66.68	11.80	18.26	3.26	62.1	2315	88.	88.
Market value per bushel											\$1.0429
Gross gain per cent											\$1.9857
											\$1.2917
											31.

‡ Estimated, market value not quoted.

TABLE XLV—NO. 4 CHIRKA †

2791	51.5	57.	3.07	64.21	16.38	16.38	3.13	56.8	2275	96.5	93.5	
2792	51.	57.	3.18	66.40	16.70	15.60	2.30	57.4	2000	93.	92.	
2860	52.	57.5	5.59	67.68	12.32	15.87	4.13	60.3	2205	78.	86.	
3928	53.	58.	2.30	64.55	17.25	16.93	1.27	62.1	2040	90.	88.	
Average	51.87	57.37	3.76	65.71	15.40	16.18	2.71	59.15	2130	89.37	89.87	\$2.1431
Maximum	53.	58.	5.59	67.68	17.25	16.98	4.13	62.10	2275	96.50	93.50	
Minimum	51.	57.	2.30	64.21	12.32	15.60	1.27	56.80	2000	78.00	86.00	
Market value per bushel												\$.9027
Gross gain per cent												\$1.2353
												42.3

TABLE XLVI—REJECTED GRADE CHIRKA †

2785	48.	54.5	2.94	64.50	16.40	15.10	4.00	55.9	2030	88.	88.	
2788	50.5	57.	3.06	64.48	16.86	14.86	4.00	55.3	2015	86.	87.5	
2789	49.	55.5	2.31	65.41	12.86	18.33	3.40	55.9	2020	93.	92.	
2790	48.5	55.5	6.10	66.28	16.20	14.86	2.66	55.9	2345	94.5	93.5	
2793	45.	53.	3.86	60.20	17.20	18.10	4.50	57.9	2240	88.	90.	
2794	47.5	54.5	3.41	62.16	17.59	15.92	4.33	57.1	2215	90.	90.5	
2795	45.	53.5	3.41	62.27	15.80	19.47	2.46	57.6	2295	92.5	93.	
2796	47.	55.	3.50	61.10	15.70	16.60	0.60	55.9	1670	84.	80.	
2797	46.	55.	3.43	62.88	18.79	14.55	3.80	57.4	2150	92.	92.5	
2798	49.	55.5	2.78	63.87	20.60	13.80	1.93	55.9	2060	91.5	91.	
2799	47.5	54.5	1.00	64.48	18.92	18.00	2.60	55.3	2070	91.	91.5	
2800	49.5	56.	6.32	63.83	16.83	15.91	3.33	57.6	2305	91.	93.	
2801	49.	55.5	1.46	64.96	17.86	16.02	1.67	56.	2365	89.5	90.5	
2802	56.	56.	...	66.36	16.86	14.72	3.06	55.6	2195	93.5	92.5	
2837	48.	53.5	4.37	66.90	16.12	15.82	2.66	57.9	2230	95.	94.	
Average	47.82	54.96	3.37	63.84	16.82	15.94	3.40	56.41	2126	90.63	90.90	\$2.0987
Maximum	50.50	57.00	6.32	66.28	20.80	19.47	6.60	57.90	2345	96.00	94.00	
Minimum	45.00	53.50	1.46	60.20	12.86	13.80	1.67	55.00	1670	84.00	80.	
Market value per bushel												\$.8614
Gross gain per cent												\$1.2692
												46.0

† Estimated, market value not quoted.

represented, namely Bluestem and Fife. Velvet Chaff having four grades and Marquis five. These four types make the bulk of the Hard Red Spring Class with about the same variation of value within the grades in each type. A wider variation is sometimes found within the grades (that are represented by a number of samples) than there is between the average of No. 1 Hard and Rejected in any type. If this is a common condition then the system of grading is a mere guess, and the factors employed to designate value are largely fictitious or assumed. This same point is borne out in the results of the work done at this Station for each of the nine years during which this work has been in progress.

The grain trade, the miller or the farmer should not be condemned or accused for the wrong that appears to exist in the present system of grain grading. This system has grown up in the past 30 to 35 years as a result of the increased production of this class of wheat, and the adoption of one factor of quality after another, generally accepted by the trade and the producer. In this way the trade has accepted this system which is now in use and quite generally believed to be the best.

It may not be for this office to condemn the system or to ever suggest a remedy; and it is advisable that caution be exercised in a study of all the facts. If the trade is satisfied with the price paid for the so called high grade wheat, and the profits from milling are remunerative, then it would appear that the injury falls on the producer. If on the other hand, the price paid for the so called lower grades of wheat is just, then the injury falls on the miller; and more especially on the local mills. It is safe to say that no mills use a greater proportion of high grade wheat in their mixture than the local mills. This being the case it increases the proportion of low grade wheat going to the terminal market, and as this better wheat is included in the six grades above mentioned and is all consumed in the manufacture of flour, it does not require one schooled in higher mathematics to see why the local North Dakota milling business is so hard to finance, or why so many local mills are standing idle and are offered for sale for less than their cost.

One cent per bushel is not very much, but one cent per bushel profit above cost of manufacture in a one hundred barrel per day mill would amount to about \$4.50 per day and in a five hundred barrel mill would be about \$22.50 per day. Either of these would be a very small unit when compared with some of the large mills at the terminals and where the cost of manufacture is reduced to a minimum this profit would amount to millions of dollars in any crop year.

Tables I to XXI, inclusive, contain the data gathered from the four well known types of Hard Red Spring Wheat, on which this discussion is based.

Tables XXII to XXVIII contain the data of some other types of Hard Red Spring that are new in this locality, some of them having been grown but one year. A comparison of these figures show some of them to have promising quality.

A comparative study of these data will show very little difference in either milling or baking quality. In fact, the differences might be considered within the scope of experimental error—when considering the average results of the type regardless of grade. The Bluestem and Fife have the six grades represented; the Velvet Chaff four grades and the Marquis five grades. Without considering the grades represented and taking the average of the total results, there is but $1\frac{1}{2}\%$ difference in amount of flour produced; the Fife and Marquis being the same; Velvet Chaff second, Bluestem third. The other highly important factor in milling results is the loss in milling in which the Fife and Marquis are again equal; Bluestem second; Velvet Chaff third. In baking results Marquis is first; Velvet Chaff, second; Fife, third; Bluestem, fourth, and if these results were obtained from a single sample rather than from a number of samples, we would say that they were near enough to be within the bounds of experimental error, except perhaps in absorption and color, which is greater than would be expected. The value per bushel of the wheat based on Bluestem as standard and according to the mill products produced would be as follows: Bluestem \$0.9887; Velvet Chaff \$0.9591; Marquis \$0.9795, showing a spread in actual value of 2.06 cents per bushel between Bluestem, Fife and Marquis and between the Bluestem and Velvet Chaff 2 cent. Table XLVII showing the average results of all the samples tested (regardless of grade) according to type.

The results in this table must not be taken as final, because of the difference in the number of samples in the different grades and by reason of some of the grades not being represented at all. This variation in the number of samples makes some difference in final results, which will be shown later.

Again, considering quality and value in wheat as two distinct factors and providing a reason for a difference in value, if any exists, it will be necessary to study the class by grades. In the preceding paragraph a study was made of the types constituting this class and very little difference was found as a whole in quality and not a very wide difference in actual value between types and it is safe to say this difference between types would vary from one to the other through a term of years. It seems safe therefore to assume that these four types composing this class of wheat are of fairly equal value. On this assumption a study of the grades in the Hard Red Spring Class is made. In these tables the values given represent 100 pounds and in the discussion this will be reduced to bushels. In table XLVIII will be found the number of samples of each type, the results by types and the average according to the total number of samples in the grade.

As a basis of market value of wheat and mill products the figures have been taken from the average quotations for the week ending December 1st, 1915, Minneapolis market, and for wheat may be found on page 598. Northwestern Miller published at Minneapolis, Minn. as follows:

	No. 1 Hd.	No. 1°	No. 2°	No. 3°	No. 4°	Rejected & No. grade
H. R. S.	\$1.0342	\$1.0292	\$.9857	\$.9402	\$.9027	\$.8614
Durum		\$.9747	\$.9447	\$.8853		\$.8194

Mill products per 100 pounds as quoted by same publication, on page 597:

Straight flour	Bran	Shorts	Mill screenings
\$2.7425	\$.9125	\$1.0875	\$.625

A study of this table will show that there is a difference between the grades. As this wheat has been graded by the rules employed by the Minnesota Grain Inspection Department, it is apparent that the system works well according to the per cent of flour produced by the different grades; there being less than 2% difference between the grades, except that of 4° and rejected; this being 2.83% and a difference of 8.22% between No. 1 Hard and rejected. Also the percentage of loss in milling gradually increases with the lowering of the test weight per bushel. It thus appears that the grades are fairly well established when considered only from the amount of flour produced and the loss in milling. A comparison of the baking results show very little difference as a whole between grades; the factor showing any marked difference being that of color, and some of the factors in the lower grades show better than in the higher grades. The scoring of all grades is well within the scoring of a straight flour in the commercial laboratory. The manufacturer of flour need not be afraid to use some wheat from all of the grades coming to him. As a matter of fact the wheat going on the market each day is usually all taken, and there is seldom any accumulation of any considerable amount of any grade over that of any other grade. Why is this so? Because the wheat going on the market is bought regardless of the amount of any grade, and an accumulation of any grade soon affects the price of that grade and as soon as the price is lower, the tendency of the industry is to increase the amount of wheat of this grade in the run going to the mill which keeps the stock of all grades down. At the end of the crop year if there is any wheat left in the terminal elevators, it is of the higher grade; showing that the wheat of the lower grades has all been disposed of and the flour made from them gone in to help make the total without any question as to any difference in quality. The baking quality of the flour produced from any given type or grade or mixture of wheat is largely determined by the judgment of the miller in charge, especially in the smaller mills. Since the advent of the wheat and flour testing laboratories, many of the larger mills are now equipped so that guessing at the result of their product is reduced to a minimum. By testing the different lots of wheat making up the blend going to the mill and testing the resulting product, they are able to keep the flour uniform. Should they find it

lacking in any factor, the blend can readily be improved by the addition of more wheat containing the factor that is deficient, or by reducing the amount of wheat containing the objectionable quality. Therefore, the baking quality can be fairly well maintained without affecting the value of the product.

While admitting the test weight per bushel as a factor to determine grade and the average results show this; a study of the application of the test weight to the individual samples shows that it is misleading and far from being an absolute guide. If the test weight was a true factor, the individual sample showing the minimum weight would produce the minimum percentage of flour. An examination of the results from the individual samples will show that this is not the rule, but in many cases the samples showing the maximum percentage of flour has a test weight below the average and also the one showing the minimum percentage of flour has a test weight above the average. The question might be raised here that the milling of the different samples might be over or under done, and to this charge it must be admitted that the science of milling is far from perfect. If the test weight was a true factor of quality, and the science of milling perfect, then we could expect the sample showing the maximum test weight to produce the maximum percentage of flour which, when baked should show at least average results. If the charge was made of any sample being over or under milled the fact would be apparent in the baking results. If the sample was over milled, the baking results would fall below the average, and if under milled, would naturally show above the average in baking results. A good illustration of these facts will be found in Table XII. Sample No. 2671 will show the maximum test weight and percentage of flour and minimum baking results; sample 2784 giving minimum percentage of flour and maximum baking results, and showing about the average test weight. It would seem quite reasonable to say that in the case of 2671, the sample was over milled. Likewise that of 2784 was under milled. In this same table (showing the results of but four samples) this fact is controverted; sample 2783 showing the minimum weight per bushel, giving about the average percentage of flour and approaching very closely the maximum baking results. Again compare the results of this sample with the one showing the minimum weight in the No. 1 Hd. Grade (Table VII). Also compare with the average and see how much bearing the weight per bushel should have on determining grade when the baking quality of the flour is considered a comparison of the percentage of flour indicates that there is apparently a true relation.

The test weight per bushel as a factor in the grain trade has a true and proper place, and was devised and in use in its proper place before our present system of grading was thought of. It is difficult to cite any authentic history concerning its origin or adoption. In all probability, it originated and was in use in Europe before we had any use for it in this country; its proper place being in connection with the shipping or exporting of grain. This country

would have no occasion to use it before the year 1840, and until a much later date most of the trading in wheat was done by measure rather than by weight. When the production of wheat in this country reached a point where there was a surplus over consumption, it became necessary to send that surplus to a foreign market. The custom was changed from trading in wheat by measure for flour and other commodities to a sale of wheat for cash and by weight rather than measure. Therefore, from the long use of the measured bushel the question arose how much should a bushel of wheat and other grain weigh. No doubt those familiar with handling the different kinds of grain answered this question; it having been established after many careful weighings of the measured bushel. At the present time the wheat produced in the part of the country where this custom was established, will weigh from 55 to 65 pounds per measured bushel, giving the general average of 60 pounds. With the advent of the export business in wheat, it became necessary to buy wheat by weight rather than by measure, because of the fact that it can be weighed more accurately than measured and can be weighed in much less time than would be required to measure it. Therefore justice and economy was the reason for adopting this method. But after the adoption of the weighing system for the purpose of purchase, the standard measure had to be maintained because shipping space is usually determined by the cubical content of the commodity shipped. In arranging for a shipment of wheat or other grain the term bushel is always taken to mean a measured bushel. If the information to the stevedore is the number of bushels by weight, the test weight per bushel must also be given in order that he may determine how many bushels of said wheat he can accommodate. This then is the place the test weight per bushel becomes a true factor in connection with wheat. (The writer does not wish the foregoing history of the evolution and growth of the test weight per bushel to be taken as authentic; for it has only been given in this way to show, if possible, that its growth into our present system of grading has some elements of reason). For example, 60,000 pounds of wheat would be 1000 bushels, if the test weight was 60 pounds, it would occupy a space of 1244.3 cubic feet. If the test weight should be 54 pounds, it would require a space of 1382.4 cubic feet; or 138.1 cubic feet more space to contain the same number of bushels. Or in other words, the hold of a vessel that will accommodate 10,000 bushels test weight 54 pounds, would hold 11,109.9 bushels test weight of 60 pounds.

Usually wheat weighing 60 pounds per measured bushel is plump, smooth in texture, and dry, thus appealing to the senses as having quality, and in all probability the men engaged in the grain trade began separating their receipts into lots according to their general appearances as they received them from the farmer. While the milling business increased very rapidly, it has not kept pace with the increase of wheat production. This gave the miller a choice of his raw material; he soon learned by experience that a bushel of wheat weighing 60 pounds for instance would produce more flour

than a bushel weighing 56 pounds. The trade soon favored the heavy weight wheat. In the early days of the milling industry, the miller was not a wheat buyer, but a manufacturer of flour, taking his pay in wheat, usually by measure. He and the farmer soon learned that it was to their mutual interest to use for their own consumption the choice wheat. If a farmer produced more wheat than was required for his own consumption the surplus was sold to a regular wheat buyer, and the milling business was confined to what was known as gristing. Gradually the consumers of flour, not engaged in the pursuit of agriculture, increased beyond the point where the miller's share (or toll) of wheat received from the farmer as pay for manufacturing the farmer's share of wheat into flour and by products was adequate to supply this demand, and the miller was forced by circumstances to buy enough wheat to supply the local demand for flour. This caused an excess production of bran and shorts. So much so that they became a drug on the market and often times a nuisance to the miller causing him trouble and expense rather than having any market value. Under these conditions the only product that had any value was the flour. Also this type of consumption was responsible for the centralizing of the milling industry. The increased production of wheat and the building of railroads for the transportation of the same to market was responsible for the location of financial centers and terminal markets, which also gave the miller opportunity to make a better selection of his raw material.

Another factor entering into the growth of our present system of wheat grading was the advent or importation of the roller process of milling, coming almost simultaneously with opening of the Red River Valley wheat farms. In ten years the total production of wheat in this country was more than doubled. To be more specific, in 1870 a total of 236 million bushels of wheat was produced and in 1880 almost 500 million bushels and this increase has been fairly well maintained to the present time, but not with as great an increase in any decade. The roller process of milling was a great forward step for the industry, but was it as great a step as it has ever had the credit of being? The roller process, a product of a man's invention, comes in to use at the same time that a superior type of wheat, a product of nature, was introduced. Man, as inventor of the roller milling process took all the credit. Because the miller with the roller process was able to produce a better flour than the consumer ever had before. The world is ready to admit that the inventor of the mill is a genius, and the trade has been accorded a credit, greater than it is entitled to. It is true that the roller process has made a vast improvement in the quality of flour produced, but without the aid of the superior types of wheat, Hard Red Spring and Hard Red Winter, would it have attained the prominence it now has? Go into a roller process mill in any of the states that continue to grow the same type of wheat as they did in 1870 and depend on getting their supply of wheat locally, and you will find that the quality of the flour remains much the same as it was in the days of stone milling; the only improvement is confined to the one

fact that more flour but of equal quality is produced from a bushel of wheat. Therefore the better quality of flour of today is due to the two types of hard wheat as well as the improved system of milling. The roller process will show a greater improvement over the stone process when milling this hard type of wheat than it does with the softer type. The advent of the hard types of wheat increased the necessity for the adoption of the new process of milling, so much so that the mills of Minneapolis (then as now the milling center for the hard red spring wheat), during the decade between 1880 and 1890, adopted the roller process almost entirely and especially the new mills that were erected there and at other points throughout this entire hard wheat section.

During the decade of rapid progress in milling the foundation of our present system of grading was evolved and as has already been shown, the value of a bushel of wheat was established on the basis of weight per bushel, the increased production of flour caused a corresponding increase of other mill products until they became almost unsalable at any price and thousands of tons were dumped into the streams and wasted. In steam power mills large quantities were burned in the furnace under the boiler so the flour was the only product of value.

From the end of this decade the food value of these different mill products have become well established and there is no part of them now that has not market value, even the impurities accompanying the wheat to the market, sell at from \$10.00 to \$30.00 per ton. In spite of the increase in the value of these products, the spread in value between the high and low grade wheat has increased rather than diminished and has varied slightly each year according to the amount of the different grades received, while the method of establishing prices remains the same with a small margin of safety against the lower grades.

Referring to Table XLVIII showing the average results of the four types by grade basing the value of the different grades of wheat on the test weight per bushel, using No. 1° Bluestem as standard as is done on the market and the value of the different grades proportionately would be as follows:

MARKET VALUE OF WHEAT SOLD ON MINNEAPOLIS MARKET. FIRST WEEK IN DECEMBER 1, '15, BASED: FIRST, ON TEST WHEAT; SECOND, ON MARKET QUOTATIONS; THIRD, ON VALUE OF MILL PRODUCTS.

Value as shown by test weight.	No. 1 Hd.	No. 1°	No. 2°	No. 3°	No. 4°	No. grade
\$1.0758	\$1.0292	\$1.0079	\$.9667	\$.9062	\$.8443	
Average of 1 week	1.0342	1.0292	.9857	.9403	.9027	.8614
Average value according to mill products	1.0508	1.0278	1.0152	1.0047	.9935	.9701

From the above figures it can be seen that the value as shown by the test weight per bushel and market quotations follow very closely except in the case of No. 1 Hd. The difference here shown between the grades as given based on the test weight and those of the market is probably more than made up by the spread of from 2 to 6 cents within the grade, and when compared with the value according to the mill products, it is plain that the use of the test

weight as applied at the present time is unfair. A strict application of the test weight gives a spread in price of 23 cents between No. 1 Hd. and rejected, while the spread in market value is 17 cents and by actual value of mill products, 8 cents between these grades; showing a discrepancy of 15 cents per bushel on the average between a strict application of the test weight and the value of the mill products, and 9 cents per bushel between market value and value of mill product.

Again applying the test weight and using the maximum and minimum within the grade as shown in Table XLVIII the spread in price is as follows: No. 1 Hd. 5.15 cents; No. 1° 1.74 cents; No. 2° 2.02 cents; No. 3° 2.68 cents; No. 4° 2.95 cents. Rejected 6.12 cents per bushel. Instances paralleling the two above mentioned, may be found in almost all the grades of all the types in which there is any number of samples given showing that the test weight when applied to the fixing of value works a hardship to the miller about equal to that which it does to the farmer, but the grain trade takes advantage of it.

The question might be raised why the commercial millers have not offered any objection to this system of grading. An examination of the ownership of the mills and elevators at the terminals and the interlocking directorate would probably explain why there has been no fault found with this system by the mills that have their own elevators in the farming districts. At the end of the year the profits on the one hand offsetting any losses that may occur on the other, and is shared by the same set of individuals and used at the same centers of finance. Such being the case it would hardly be expected that any objection would be offered to a factor having such a universal acceptance. The foreign miller, the local miller, not so favorably located and the farmer are the ones that the working of this system injures. Some may take exception to this statement of the universal acceptance of the test weight per bushel. Let anyone having an adverse opinion, take a sample of wheat to any local mill or elevator, or any terminal mill or elevator or to any state inspection department, and they will find in the mill or elevator, local or terminal, just three questions to be settled between themselves and the wheat buyer, and in the inspection department but two to be settled. In the mill or elevator; first, dockage and if not settled by mutual consent, a set of standard sieves are used under certain definite rules and the amount of dockage per bushel determined. Second, grade and if that cannot be settled by mutual consent, the chondrometer kettle is used which gives the test weight which usually establishes the grade. Third, the price that will be paid within that grade and if the test weight approaches the minimum allowed for that grade, the price is almost always sure to follow. The inspection departments have only the dockage and grade to settle and a large number of sales are made by the commission men for their clients on the opening or closing bid in the particular grade on the specified market.

The mills located at the terminals buy most of their wheat after examining composite samples of the individual cars. The samples are taken by the state for the inspection department, the grade and dockage are fixed and the sample delivered to the grain exchange and offered for sale. The buyers are representatives from the mills, elevators and export commission firms. The competition on these markets is usually between the buyers for the different mills. The elevators and commission men are satisfied to take what is left and at a price indicated by the bid for the respective grade at the close of the market session. Since the adoption of testing laboratories by these mills, the records of the market show that the spread in price within the different grades are being increased, which would indicate that these buyers are using actual knowledge of milling quality of the individual sample as a basis of value rather than test weight. The grade being established by the Inspection Department, they are entitled to the wheat at a price varying within certain fixed limits, they know from actual experimental knowledge the samples that have high milling value or that contain the factors of quality that they need to maintain the standard to which they are holding their output of flour. This leaves the balance to be taken at the closing bid of the market session or at the opening bid of the following session.

Again referring to Table XLVIII for a comparison of value: the number of samples of each of the four types is shown assuming these to be of equal amount and calculating the per cent of the different grades of each type. Using the market value of the No. 1° Bluestem as a basis, and according to the value of the mill products produced the value per bushel for the different types and grades would be as shown in Table XLVIIIa.

THE AVERAGE OF THE FOUR TYPES AS SHOWN IN TABLE XLVIII BASED ON NO. 1st BLUESTEM AS STANDARD, ALSO THE PERCENTAGE OF THE DIFFERENT GRADES AND THE VALUE OF MILL PRODUCTS BASED ON THIS PERCENTAGE.

Type of wheat	No. 1 Hard value	Per cent of wheat	No. 1 st value	Per cent of wheat	No. 2 nd value	Per cent of wheat	No. 3 rd value	Per cent of wheat	No. 4 th value	Per cent of wheat	Rejected value	Per cent of wheat
Bluestem	\$1.0591	3.85	\$1.0292	57.90	\$1.0149	58.33	\$1.0007	68.	\$.9941	75.75	\$.9731	84.28
Fife	1.0556	26.92	1.0453	15.79	1.0253	18.33	1.0298	12.	1.0027	15.15	.9741	28.68
Velvet chaff	1.0462	16.38	1.0628	6.26	1.0089	18.88					.9272	7.44
Marquis	1.0494	53.85	1.0269	21.05	1.0202	19.46	1.0037	20.	.9731	9.10	.....	0.00
Average	1.0518	100.	1.0160	100.	1.0161	100.	\$1.0114	100.	\$.9900	100.	\$.9581	100.
Market Value	.....	15.11	.....	22.09	.....	20.93	.....	14.53	.....	19.18	.....	8.16=100
Difference	1.0342	.....	1.0292	.....	.....	.....	.....	.....	.....	.....	.....	.....
	\$.0175	.....	\$ +.0106	.....	.....	.....	.....	.....	\$ .9027	.....	.....	.....
							\$.0711		\$.0878		\$.0987	

TABLE XLIX GENERAL AVERAGE OF ALL TYPES BASED ON SAME NUMBER OF SAMPLES AS BLUESTEM AND VALUE OF WHEAT BASED ON THE BLUESTEM GENERAL AVERAGE.

Type of wheat	Weight per bushel After cleaning	Loss in cleaning	Total flour	Bran	Shorts	Loss in milling	Water absorbed	Volume of loaf	Score	Texture	Value of 100 lb. wheat	Value products from 100 lb. wheat	Wheat per bushel based on Bluestem	Value products per bushel	Gross gain in milling
Bluestem	54.46	3.35	68.76	14.85	14.29	2.10	59.53	2286	89.52	91.68	\$1.5909	\$2.1976	\$.9545	\$1.3185	38.2
Fire	54.95	58.44	69.64	13.57	15.21	1.58	60.93	2290	91.53	91.07	1.5909	2.2204	.....	1.3922	39.8
V. chaff	55.03	58.34	66.38	14.69	16.06	2.87	60.94	2311	88.69	90.81	1.5909	2.1475	.....	1.2685	34.8
Marquis	55.07	58.78	68.14	13.67	15.63	2.56	61.34	2485	92.80	93.88	1.5909	2.1852	.....	1.3111	37.7
Pioneer	56.94	59.12	69.88	10.06	17.18	2.24	61.89	2644	92.55	95.09	1.5909	2.2242	.....	1.3345	39.8
Prelude	54.35	57.31	70.77	11.71	15.33	2.19	61.60	2558	86.30	91.98	1.5909	2.2369	.....	1.3421	40.6
Durum	56.27	58.47	68.22	11.84	18.00	1.94	61.03	2040	88.24	90.85	1.5909	2.1981	.....	1.3189	38.3
H. R. W.	56.50	60.34	70.33	13.16	13.68	2.81	61.60	2348	80.76	89.45	1.5909	2.2134	.....	1.3280	39.1
Manchuria	55.29	58.82	65.63	12.18	18.21	5.98	58.72	1893	80.95	78.04	1.5909	2.1248	.....	1.2749	33.6
Ghirka	54.77	59.33	66.81	13.74	16.62	2.83	60.71	2222	89.69	89.13	1.5909	2.1567	.....	1.2940	35.8

In discussing Table XLVII on page 80 of this bulletin as stated the values there given should not be taken as final and an explanation was promised later. The results as shown in Table XLVII are the average of all the samples within the type regardless of grade and are therefore a general average of type and were used for the purpose of showing in a general way the difference in type. The results as shown in Table XLVIII are the average of the results based on the number of samples of the different types within the grade, and consequently are about what might be expected from milling the same percentage of the different types here shown of any of the grades, and the value per bushel given in the above table are fairly comparable. Referring to Table XLVIIIa it will be noticed that the difference between No. 1 Hard and Rejected grades according to market value and percentage of grade is 17.28 cents and for value of mill products 9.37 cents—ranging by grade from 1.06 cents too high for No. 1° to 9.67 cents too low for rejected—and showing a gradual increase of loss with the lowering of the grade. A mixture of wheat of the different types and percentage of types and grade as here shown will amount to a net loss or difference in value of \$4.1086 on each 100 bushels milled. This difference in price therefore would amount to over four million dollars on a crop of 10 million bushels. The percentage of the different grades as here shown would probably not be a fair division of this crop, which would cause the above deductions to be unfair if applied to the results of the total crop. For instance if a blend should be made of the same percentage of the different grades as shown above, and market value compared with actual value, the difference would be 4.1086 cents per bushel.

To get an idea of what the percentage of the different grades are for this crop turn to page 598 of the Northwestern Miller dated Dec. 1st, 1915 and find a report of cars of the different grades, and if it is assumed that each car contained the same number of bushels the result would be as follows:

			Market value per bushel		Value accord- ing to mill products per bushel
No. 1 Hard	218 cars—	5.65% of receipts	@ \$1.0342=	\$0.0584	@ \$1.0518=\$0.0584
No. 1°	1468 cars—	38.00% of receipts	@ 1.0292=	.3911	@ 1.0160= .3811
No. 2°	1132 cars—	29.35% of receipts	@ .9857=	.2883	@ 1.0161= .2982
No. 3°	516 cars—	13.35% of receipts	@ .9402=	.1255	@ 1.0114= .1330
No. 4°	330 cars—	8.55% of receipts	@ .9027=	.0772	@ .99 = .0886
Rejected	59 } 196 cars—	5.10% of receipts	@ .8614=	.0439	@ .9581= .0490
No. grade 137					
Total	3860 cars—	100% of receipts		.9854	1.0115

Using these percentages of the different grades at the value per bushel shown in the table on page 82 and the loss or difference in value, would be 2.69 cents per bushel. It must be borne in mind that this is over and above the profit in milling as shown by the No. 1° Bluestem used by the market as standard.

Table XLIX will show the results of all of the types received at this station. The results were averaged according to the number of samples of Bluestem, and where grades were lacking the samples

were omitted, hence Bluestem and Fife are the only types with all the grades represented.

The results in this table are similar to those found in Table XLVII and are not final but show the comparative value in a general way.

Summing up this whole matter as to the trouble resulting from the sale of wheat it may be safely charged to the system used in grading. The remedy for this injustice, if attained, must come by a proper education of the grain trade generally to the facts shown by this data. It is evident that the majority of men engaged in the grain trade are not aware of the true milling value of the different lots of wheat coming to them and that they are conscientious in their application of the system in vogue, while it is the strict application of this system that is working such a hardship on our local miller, as well as the farmers. If the local millers were aware of the actual value of the so called lower grades of wheat, they would use more of them in their mixture, thus reducing the cost of their raw material. At the same time they would reduce the amount of low grade wheat going to the terminal market; thereby increasing the cost of the raw material to their competitors.

To illustrate the working of the system of grading combined with the methods of marketing take 60,000 pounds of wheat of each of samples 2677 and 2849 Table III and follow them to market and then to the mill at the terminal and see what happens.

Lot 1 (Sample 2677) contains 60,000 pounds No. 2° Bluestem with 13½ pounds dockage, which would be 773 bushels and 30 pounds clean wheat at average market value \$.9857, would be \$762.44, less freight, \$60.00, would net to the farmer \$702.44. The miller who bought this lot of wheat had it unloaded at his mill and in the process of manufacture it would be converted into the following products and values:

Flour	33239lb=	\$ 911.58	Total value	\$1122.90
Bran	7147lb=	65.22	Total cost wheat	762.44
Shorts	6525lb=	61.17		
Screenings	13590lb=	84.93	Gain	\$360.46 or 47.28%
Loss in milling	399		Screening	84.93
Loss in milling	399		Less screening	\$275.63 or 36.13%

Cost of wheat \$.9857 value of mill products from a bushel \$1.45 and without considering the screenings, \$1.34 per bushel.

Lot 2 (Sample 2849) contains 60,000 pounds No. 2° Bluestem, 1¼ pounds dockage, would be 971 bushels and 6 pounds clean wheat at market value \$.9857, would be \$965.10, less freight, \$60.00, would net to the farmer \$905.10. This lot handled the same as the above would result as follows:

Flour	36317lb=	\$ 995.99	Total value	\$1192.99
Bran	10339lb=	94.35	Cost wheat	965.10
Shorts	8718lb=	94.81		
Screenings	1254lb=	7.84	Gain	227.89 or 23.61%
Loss in milling	3372lb=		Screenings	7.84
	60,000lb=	\$1192.99	Less screenings	\$220.05 or 22.80%

The value per bushel in this case being \$1.22 and without considering the screening, \$1.21 per bushel.

In the case of the first lot, it netted the farmer \$.9081 per bushel and the second lot \$.924. The profit to the miller over cost of raw material in first lot would be \$.4643 and without considering screenings, \$.03643 per bushel. In the second lot it would be \$.2343 and without screenings \$.2243. And the miller's gross profit over the net value to the farmer in the first lot was \$.5419 and without the screenings \$.04319 per bushel. And in the second lot \$.296 and without the screenings \$.286 per bushel.

According to our present system of grading and marketing these two lots of wheat are assumed to be of equal value per bushel. According to practice there is a difference between the two lots to the farmer of \$.0159 per bushel. To the miller the order is reversed. The lot netting the farmer the least per bushel, nets the miller double the profit of the other lot, or lot 1 nets the miller \$.4643 and lot two \$.2343 cents per bushel, or a percentage of profit in lot 1 over cost of wheat of 47.28 per cent, lot 2, 23.61 per cent. The percentage is also given without considering the screenings which are more than one and a half times as great in lot 1 as in lot 2.

These are extreme cases but they occur within the same grade. Now the question might be raised; would there be any benefit to the farmer or miller to buy on actual value? The answer according to the data presented is, yes! It has been shown that on the average and according to the percentage of the different grades as received here, the loss or difference is \$.0411 per bushel and according to the percentage of the different grades received at Minneapolis for one week, the loss or difference would be \$.0269 per bushel and on the North Dakota 1915 crop according to the estimate of yield by United States Department of Agriculture, would amount to a loss of \$3,119,200.00.

Using the same values for wheat and the different mill products as used above, and taking a carload of 60,000 pounds of wheat equal to the average of the No. 1° Bluestem shown in Table II, the results would be as follows:

Flour	41706 lb = \$1142.75	Total value	\$1310.11
Bran	7642 lb = 69.54	Total cost of wheat	1006.04
Shorts	8200 lb = 89.38		
Screenings	1350 lb = 8.44	Gain	304.07 = 30.22%
Loss	1102 lb =		

Total 60,000 lb = \$1310.11

60,000 pounds wheat equal to average of No. 4° Bluestem from Table V.

Flour	38775 lb = \$1062.44	Total value	\$1255.19
Bran	9656 lb = 87.87	Total cost of wheat	867.85
Shorts	8294 lb = 90.40		
Screening	2316 lb = 14.48	Gain	\$ 387.34 = 44.63%
Loss	959 lb =		

Total 60,000 lb = \$1255.19

There is some wheat in almost every crop year that should not be used for human consumption, but should be condemned and only allowed to be sold as animal food, and if not fit for that purpose, should not be allowed on the market at any price. The same as is done with meat and many other food products, but under the present system, the majority of this low grade wheat is bought by the elevator companies and mixed in small quantities and eventually finds its way into the flour of the consumer. In many instances the price paid is far below what it is actually worth for feed. Many of the complaints from the consumers coming to the miller are just and could be attributed to this cause.

Name and location of individuals from whom the samples were received.

Lab. No.	Name	City	County	State
2469	W. H. Pray	Valley City	Barnes	N. D.
2470 to 2521	Prof. R. C. Donaghue	Agr. College	Cass	N. D.
2608	Bemmels Mill	Lisbon	Ransom	N. D.
2609 to 2610	Geo. Hoople	Hoople	Walsh	N. D.
2611	Christ Flum	Milton	Cavalier	N. D.
2612	Andrew Fulm	Milton	Cavalier	N. D.
2613 to 2614	F. A. Wilhelm	Jamestown	Stutsman	N. D.
2615	Farmers Elevator	Wimbleton	Barnes	N. D.
2669 to 2674 Inc.	H. J. Boyts	Minnewaukon	Benson	N. D.
2675-2676	C. F. Anderson	Rugby	Pierce	N. D.
2677	C. D. Parkman	Finley	Steele	N. D.
2678 to 2680 Inc.	E. Lavik	Rugby	Pierce	N. D.
2681 to 2682	Chas. Shippy	Hope	Steele	N. D.
2683	A. Skavhang	Adams	Walsh	N. D.
2684	F. W. Keetzman	Lakota	Nelson	N. D.
2710-2711	J. Southam	Mohall	Renville	N. D.
2712-2714 Inc.	Majoris Bros.	Larimore	Grand Forks	N. D.
2735-2736	L. W. Beckwith	Oakes	Dekey	N. D.
2737	J. H. Whitcher	Valley City	Barnes	N. D.
2738-2739	C. S. Roberts	Dawson	Kidder	N. D.
2757 to 2759 Inc.	G. E. Edwards	Minot	Ward	N. D.
2760	J. Southam	Mohall	Renville	N. D.
2761	B. F. B. Green	Sherwood	Renville	N. D.
2762	M. H. Hagen	Mohall	Renville	N. D.
2763	Thos. Fitzmaurice	Mohall	Renville	N. D.
2764	Henry Renfeldt	Minot	Ward	N. D.
2765	Thos. Brown	Mohall	Renville	N. D.
2766-2767	Henry Renfeldt	Minot	Ward	N. D.
2768	Wm. Hadler	Surrey	Ward	N. D.
2769	W. A. Peck	Logan	Ward	N. D.
2770	Will Hussey	DesLacs	Ward	N. D.
2771	W. A. Peck	Burlington	Ward	N. D.
2772	O. Brown by W. A. Peck	Not known		
2773	Burlington El. Co.	Burlington	Ward	N. D.
2774-2775	Logan El. Co.	Logan	Ward	N. D.
2776	Joe Parkle	DesLacs	Ward	N. D.
2777	Burlington El. Co.	Burlington	Ward	N. D.
2778	Winners El. Co.	Carpio	Ward	N. D.
2779	Logan El. Co.	Logan	Ward	N. D.
2780 to 2802 Inc.	L. R. Waldron	Dickinson	Stark	N. D.
2803	J. F. Jaberg	Sanborn	Barnes	N. D.
2804	Peter Thorson	Voltaire	McHenry	N. D.
2805 to 2807	Joe McCrary	Carrington	Foster	N. D.
2814	Equity El. Co.	Tappen	Kidder	N. D.

Lab. No.	Name	City	County	Sta.
2816	Thos. Pendry	Jamestown	Stutsman	N. D.
2817-2818	D. J. Stiner	Beach	Golden Valley	N. D.
2825-2826	O. H. Dolve	Hatton	Trail	N. D.
2827 to 2828	Jos. Meaers	Ross	Mountrail	N. D.
2829-2830	M. W. Schnider	Wales	Cavalier	N. D.
2831	Angus V. Moritz	Dresden	Cavalier	N. D.
2832	C. A. Stebbins	Granville	McHenry	N. D.
2833	Carl Anderson	Farland	McKenzie	N. D.
2834	Christ Jensrude	Arnegard	McKenzie	N. D.
2835-2836	F. W. Kietzman	Lakota	Nelson	N. D.
2837 to 2838	Alex Morrison	Bathgate	Pembina	N. D.
2839-2840	W. C. Carincross	Wahpeton	Richland	N. D.
2841-2842	Kurtz Bros.	Hazleton	Emmons	N. D.
2843-2844	Geo. Kline	Mott	Hettinger	N. D.
2847	No information given			
2849 to 2851 Inc.	Anton Peterson	Washburn	McLean	N. D.
2852-2853	T. C. Askland	Reeder	Adams	N. D.
2855 to 2867 Inc.	Highmore Exp. Sta.	Highmore		S. D.
2879 to 2891 Inc.	Brookings Exp. Sta.	Brookings		S. D.
2893 to 2914 Inc.	Williston Exp. Sta.	Williston	Williams	N. D.
2915 to 2922 Inc.	Moccasin Exp. Sta.	Moccasin		Mo.
2923 to 2932 Inc.	Archer Exp. Sta.	Archer		Wyom.
2933 to 2942 Inc.	Dickinson Sub Sta.	Dickinson		N. D.
2943 to 2953 Inc.	Newell Exp. Sta.	Newell		S. D.
2957	Farmers Ele. Co.	Mapleton	Cass	N. D.
2958	Louis Noltimier	Valley City	Barnes	N. D.
2963		Moose Jaw	Sask.	Can.
2967	H. B. Wasson	McClusky	Sheridan	N. D.
2968	Clarence Goldhamers	Edmore	Ramsey	N. D.

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35

North Dakota
Agricultural Experiment Station

Other Grains Than Wheat in Bread Making

By W. L. Stockham

and

Milling Value of Barley

By Thomas Sanderson

Bulletin No. 123

Agricultural College, North Dakota

October 1917

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* Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

Baking value of rye flour, page 100.

Bread from rye and wheat flour mixtures (photographs and tabular data), pages 101 and 102.

Baking value of high and low grade barley flours, pages 100 and 102.

Bread from barley and wheat flour mixtures (photographs and tabular data), pages 101 and 102.

Gluten an essential for raised bread and substances which may modify it, pages 102 and 103.

The advisability of increasing the percentage of wheat flour by including some of the outer material of the kernel, pages 102 to 104.

Corn in bread making, page 104.

Kaffir, millet, and emmer for bread making, pages 104 and 105.

Economic comparison of cereals (tabular data), page 105.

Barley as a human food, page 106.

Description of samples and milling results, page 106.

Milling equipment and blending of flour, pages 106 and 107.

The value and economy of the use of barley as a food product, page 107.

OTHER GRAINS THAN WHEAT IN BREAD MAKING

By W. L. Stockham

The shortage in wheat may make it necessary to mill more of the wheat into flour than has been the custom and to use other grains to some extent in bread making. The availability of other cereals is dependent not only on the quantity produced but upon special milling facilities and an understanding of how to properly prepare them for use. It is also necessary to determine the quality of bread that can be made from them either alone or in combination with wheat flour.

Rye flour is similar to wheat flour in production factors. It is commonly used in connection with wheat flour in restaurants and since it can often be purchased somewhat cheaper than wheat flour more of it should be used in the home. Rye flour when used alone makes a bread with a strong rye odor and flavor. This is less pronounced in the higher grades which are likely the only ones to be used alone. To determine the relative value of the lower grades of rye flour, President Ladd secured two samples of rye flour from a commercial rye mill. One a pure medium colored rye flour, representing between 75 and 80 percent of the kernel and designated as No. 100, and a lower grade from a similar percentage extraction designated as No. 15X, the better half of the flour having been taken out as white rye flour. Assuming that a light color would be of no special value in blends of this kind, and in the interests of economy, a low grade wheat flour was used with the rye. Photographs of the bread are shown in figures 1 and 2.

The wheat flour used in the blends when baked alone had only a fair flavor for a low grade wheat flour of its class. Those who have not developed a taste for rye bread would likely prefer that containing the smaller amounts of the straight rye flour, but those who like the rye would probably prefer about a 25 percent mixture of the lower grade No. 15X rye. For most people any higher percentage would be too strong and the difficulty in baking would lead to greater loss of the finished product.

Because of ease of manipulation and greater strength the higher grade wheat flours can carry more rye but might not be as satisfactory to many as the lower grade blends because of the lower price of the latter. The lower grade rye has a much greater water absorbing power than the wheat or the higher grade rye flour.

But little barley has been milled in the United States to date and just what its possibilities are, is not very well understood. Some experiments were made in the experimental mill to show what could be expected of it. Its milling value is discussed in connection with this paper by Thomas Sanderson.

A series of blends with the two grades of barley flour with a wheat flour were baked (see fig. 3) to determine its adaptability for bread making. As much as 25 percent of the higher grade barley flour in the blend is hardly noticeable and produces a very mild barley flavor, but when barley is milled closer, its flavor is so much stronger that 25 percent of barley in the blend is about all it can carry. Bar-

TABLE I. BAKING REPORT ON COMMERCIAL RYE FLOUR AND RYE WHEAT BLENDS

Sample	Water absorption	Loaf volume	Color score	Texture score	Flavor	Remarks
No. 15X Rye ¹	73.5	760	10	10	Very strong, bitter	Extremely dark, very compact
No. 100 Rye ²	62.1	750	28	10	Very strong, bitter	Extremely dark, very compact
2nd clear wheat flour.....	87.7	1900	55	78	Characteristic 2nd clear	Brownish
No. 15X rye 10% & 2nd clear wheat flour 90%.....	64.7	1780	42	72	Mild rye flavor	Dark brown
No. 15X rye 15% & 2nd clear wheat flour 85%.....	66.2	1810	37	65	Rye flavor	Dark brown
No. 15X rye 25% & 2nd clear wheat flour 75%.....	67.7	1400	35	50	Decided rye flavor	Very dark brown
No. 15X rye 50% & 2nd clear wheat flour 50%.....	73.5	1120	20	43	Very strong rye, after taste	Extremely dark
No. 100 rye 10% & 2nd clear wheat flour 90%.....	62.6	1950	50	76	Mild rye flavor	Dark brown
No. 100 rye 15% & 2nd clear wheat flour 85%.....	62.1	1710	44	73	Mild rye flavor	Dark brown
No. 100 rye 25% & 2nd clear wheat flour 75%.....	62.4	1480	40	65	Rye flavor	Dark brown
Good grade wheat flour used in the following blends.....	64.1	2170	94	82	Mild rye flavor	Creamy gray
No. 15X rye 15% & wheat flour 85%.....	64.1	2010	48	83	Mild rye flavor	Brownish
No. 100 rye 15% & wheat flour 85%.....	61.2	2070	68	87	Mild rye flavor	

¹Low grade rye flour.²Straight grade rye flour.

TABLE II. BAKING RESULTS WITH BARLEY FLOUR AND BARLEY-WHEAT BLENDS

Sample	Water absorption	Loaf volume	Color score	Texture score	Flavor	Remarks
High grade barley flour ¹	55.6	1250	30	45	Somewhat strong	Very dark, grayish brown
Wheat flour used in blending.....	64.1	2170	94	92	Wheat bread flavor	Creamy gray
10% high grade barley flour.....	65.3	2110	88	91	Presence of barley not noticeable	Gray
25% high grade barley flour.....	61.5	2080	81	89	Mild barley	Very gray
Low grade barley flour ²	78.2	740	28	10	Very strong, somewhat bitter	Very dark brown
10% low grade barley flour.....	67.7	2040	62	86	Barley flavor	Bluish gray
25% low grade barley flour.....	67.7	1700	49	68	Strong barley flavor	Very dark gray

¹Thirty percent of entire kernel. No. 3573.²Sixty-eight percent of entire kernel. No. 3673A.

ley dough is more sticky than wheat dough but less sticky than that from rye and like the latter when milled close and baked alone is too strong to be relished by the average American. It also has a greater water absorbing power than wheat but neither barley nor rye retain their moisture as well as the wheat. Straight rye and barley flour each make a very compact loaf. The denser loaves require more time in baking which tends to equalize the increased water absorption by permitting more evaporation.

When wheat flour is wet the proteins contained within it adhere to form a sticky, elastic mass known as gluten. The gluten, encasing starch and other constituents forms the dough. Gas formed by the action of yeast makes bubbles within the dough which cannot escape because of this gluten. The increase in size of these bubbles causes the bread to rise. By kneading the dough the yeast cells which have become more numerous thru division are uniformly distributed thruout the dough and gas is produced at an increased number of points. The bubbles will thus be more abundant but smaller and of more uniform size. When the dough is baked the places where the gas was held remain as holes. If the dough has over-raised or is too weak the gluten walls between the gas bubbles give way, forming larger bubbles which results in a coarse bread or a collapse. Wheat is the only one of the commonly used cereals which contains gluten. If one desires to make a good light bread, wheat flour must form the basis for it and the limit to the amount of other cereals which may be added

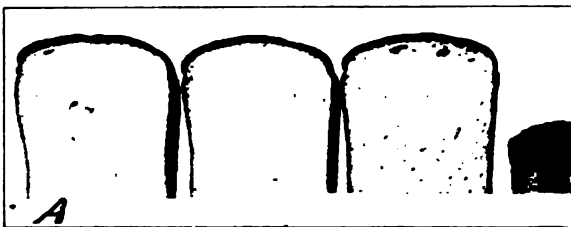


Fig. 1—Rye and rye-wheat

Straight grade wheat flour

15 percent rye No. 100

15 percent rye No. 15X

Straight rye No. 100

25 percent rye No. 100

15 percent rye No. 100

10 percent rye No. 100

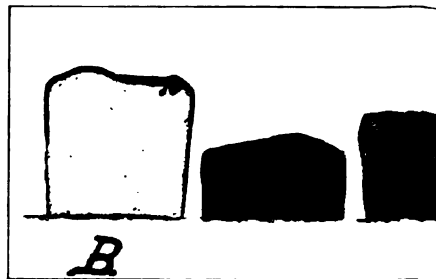


Fig. 2—Rye and rye-wheat

Wheat flour, 2nd clear

Low grade rye No. 15X

50 percent rye No. 15X

25 percent rye No. 15X

10 percent rye No. 15X

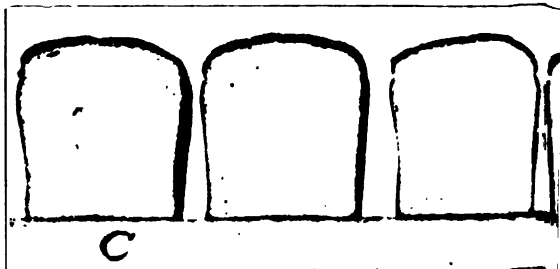


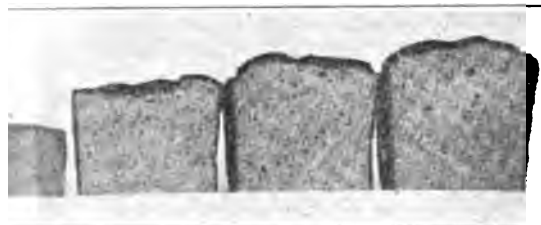
Fig. 3—Barley and wheat

Wheat flour used in blending

High grade barley flour¹ 10 percent

High grade barley flour 25 percent

¹High grade, 30 percent of kernel, No. 3571



mixtures—left to right.

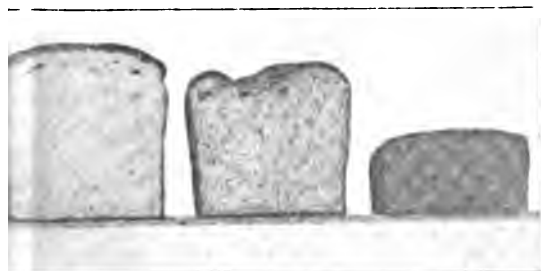
lended with straight grade wheat flour

...Blended with 2nd clear wheat flour



mixtures—left to right

...Blended with 2nd clear wheat flour



or mixtures—left to right

Lower grade barley flour² 10 percent.

Lower grade barley flour 25 percent.

Lower grade barley flour alone.

wer grade, 68 percent of kernel, No. 3573A.

is determined by their influence in weakening, as well as diluting the gluten. Protein material from other cereals, eggs and other substances may retain gas but they do not compare with wheat gluten for bread making and have not the body or tenacity to bear much pressure. Gluten is affected differently by acids, salts, sugar, fats, other proteins and the ferments secreted by the germs of the cereals. Substances like starch are more or less inert but all have a diluting and modifying influence. The protein substances in the outer wheat coats and in the other cereals with the exception of gliadin in rye are not constituents of gluten and their addition almost always affects the elasticity of the gluten and dough adversely, lowering its power to hold gas.

The ability of a flour to make a large good-textured loaf is its 'strength'. In some cases lack of gas production causes weakness but this can be overcome artificially. Lack of ability to retain the gas generated by the yeast is more often the difficulty and usually cannot be overcome except by mixing with flour of superior strength.

SHOULD THE ENTIRE WHEAT KERNEL BE REDUCED TO FLOUR OR THE PRODUCT MADE CHEAPER BY ADMIXTURE OF FLOUR FROM OTHER CEREALS?

The modern milling process is very well developed and although family patent grades have the preference, practically all of the endosperm of the kernel that can be recovered is marketed in the various grades of white flour. When the wheat is first crushed on the rolls some flour is formed and this with that last removed from the shorts

particles goes into the lower grades. The patent grades come from the reduction of the large particles of endosperm after they have been purified by air currents. All the grades of flour that people care for is used for human consumption and the remainder is used for paste or as stock feed. Any increase in the percentage of flour would render the dough more sticky and "runny" and it would also result in a waste of more bread because of the introduction of ferments, the inclusion of more bacteria, and the decrease in gas retaining power, and this in turn would require more skill in baking. With the higher grade flours the method of making bread may be modified freely without seriously injuring the product. With the lower grades fermentation is quickened, the periods of sponging and raising may be changed only within narrow limits and the temperature must be more carefully controlled. Such increase in percentage of flour would also render the introduction of other cereals less satisfactory. Those desiring the laxative properties in the coarser part of the wheat kernel can add the bran and shorts separately. The whole wheat bread of the housewife is usually made from three-fourths or more high grade white flour and one-fourth or less whole wheat flour. Such a loaf would be very much better than one of similar color made by increasing the percentage of flour by close milling as the former would contain the higher percentage of strong flour.

From the nutrition experiments of Hart and McCollum of the Wisconsin Experiment Station and the reports of Edgar of the conditions in Belgium, it is evident that where variety of food is very limited and a single product forms a large portion of the ration white bread (about 75 percent or less of the wheat made into flour) would be very much safer than that made by reducing 80 percent or more of the wheat to flour. This is because of a toxic substance in the germ of the wheat kernel which could not then be eliminated. There is no reason however why a longer (a higher percentage) patent, a straight, or a low grade flour should not be more generally used.

Corn is used practically alone in some forms of bread. It is not often used as the only bread in the home and is in general favor only when warm. Mixed with wheat flour up to 25 percent it makes a satisfactory raised bread for general use. Its germ must be almost completely separated in the milling process to prevent souring when stored. Like whole wheat flour and others which are not bolted thru fine cloth it may become infested with moth or live weevil and therefore should be used as soon as possible after milling.

From the preliminary experiments published in the American Food Journal, June, 1917, by E. H. S. Bailey and W. S. Long it appears that flour from reduced rolled oats could be used to advantage in admixture with wheat at the present price of oats. In bulk they can be obtained at about half the price of wheat flour. The hull constitutes about 30 percent of the kernel. The higher the percentage of oat flour mixed with wheat flour the more compact the loaf becomes.

Kaffir, millet, and emmer may at a time be given consideration by the public. Kaffir would rank long with corn. Millet is used extensively in Asia, Southern Europe, and Egypt and is fairly alatable in mixtures with wheat flour. Emmer makes a smaller loaf, darker in color, and stronger in both odor and flavor than wheat.

Table III was prepared to aid the reader in making an economic comparison of other cereals with wheat. Wheat brings the highest price per unit weight. If the entire kernels were used as food and prices remained relatively the same as the averages of the past 40 years the other cereals would be competitors of wheat. There appears to be no data for comparing the cost of manufacture of the different flours. Of all these cereals, rye, corn, and wheat are the only ones extensively milled and the product marketed in the United States.

The selection of substitutes or supplements may be determined by personal preference rather than necessity. In either case the facts above cited may aid in making a choice.

TABLE III. ECONOMIC COMPARISON OF OTHER CEREALS WITH WHEAT

Crop	Pounds per bushel	Yield per acre, U. S. average, 40 years	Yield per acre in wt. of grain, wheat as the unit.	Cost per acre to produce, (from Minn. Ex. Sta. 1908-1912	Cost per acre to produce, wheat as the unit	Average price per bushel 1911-14.	Average price per unit weight, wheat as the unit	Gross returns per acre, wheat as the unit
	Pounds	Bushels		Dollars		Cents		
Wheat	60	13.3	1.00	10.78	1.00	84.9	1.00	1.00
Rye	56	14.56	1.02	10.83	1.00	74.9	.945	.96
Barley	56	23.9	1.68	11.16	1.04	61.4	.775	1.80
Corn	56	25.	1.75	14.52	1.35	60.8	.767	1.84
Oats	32	27.95	1.12	12.02	1.12	40.0	.81	.90

MILLING VALUE OF BARLEY

By Thomas Sanderson

In the adoption of barley or any of the cereals as human food products, there are at least three important factors to be considered namely; comparative food value, amount of increase of food products and the economic use of the same. The two latter items are considered in this article.

A sample of barley was secured from the Wisconsin Experiment Station. It was the common type and graded No. 3 under the North Dakota grades. It was designated as Wisconsin No. 5 a pure strain grown in Rock County, Wisconsin. This sample was divided into lots for a milling and baking test. Lot 1 was given laboratory number 3573 and Lot 2, 3573A, Lot 1 was milled on the large experimental mill equipped for milling wheat and Lot 2 was milled on the small two stand mill on which the bolting could be done on different fineness of bolting cloth to secure a higher percentage of flour. The following table shows the percentage of the different products obtained from these two lots.

TABLE IV. MILLING DATA ON BARLEY

Lab. number	Flour	Hulls	Other offal	Loss in milling	Barley per bbl. (196 lbs.) of flour	Bu. and lbs. per bbl.	
	Percent	Percent	Percent	Percent	Lbs.	Bus.	Lbs.
Lot 1—3573	30.24	22.75	44.45	2.56	649	13	25
Lot 2—3573A ..	68.60	17.07	9.40	4.93	286	5	46

A study of this table shows that barley cannot be milled successfully with the same equipment as wheat, and in the opinion of the writer a rye mill would not be an efficient equipment for producing results comparable with that of Lot 2 in the above table. Therefore to secure results similar to those for Lot 2 a specially equipped mill will be required. It might be possible for the baker and housewife to do the blending, but more definite and satisfactory results would be obtained in a properly constructed blending plant.

Some millers may attempt to mill the barley as a blend with wheat. This practice will prove a failure as is shown in Special Bulletin Vol. 11, No. 18, (North Dakota Experiment Station) page 31, issued August 1913 by the Food Commissioner. This test shows that the addition of 15 percent of barley to a No. 2 Northern hard red spring wheat milling sample reduced the flour 7.5 percent, increased the loss in milling 0.62 percent and gave a very slight reduction in the quality of bread; indicating that a very small amount of the barley had been bolted as flour, and that the bulk of it had gone into the feed.

If a scarcity of wheat should force the adoption of barley as a bread making grain, it would be possible to equip mills to produce flour comparable with that shown from Lot 2 or any intermediate

grade between these two lots that might be desired; or it might be possible to get as high as 50 percent or more with the ordinary rye mill.

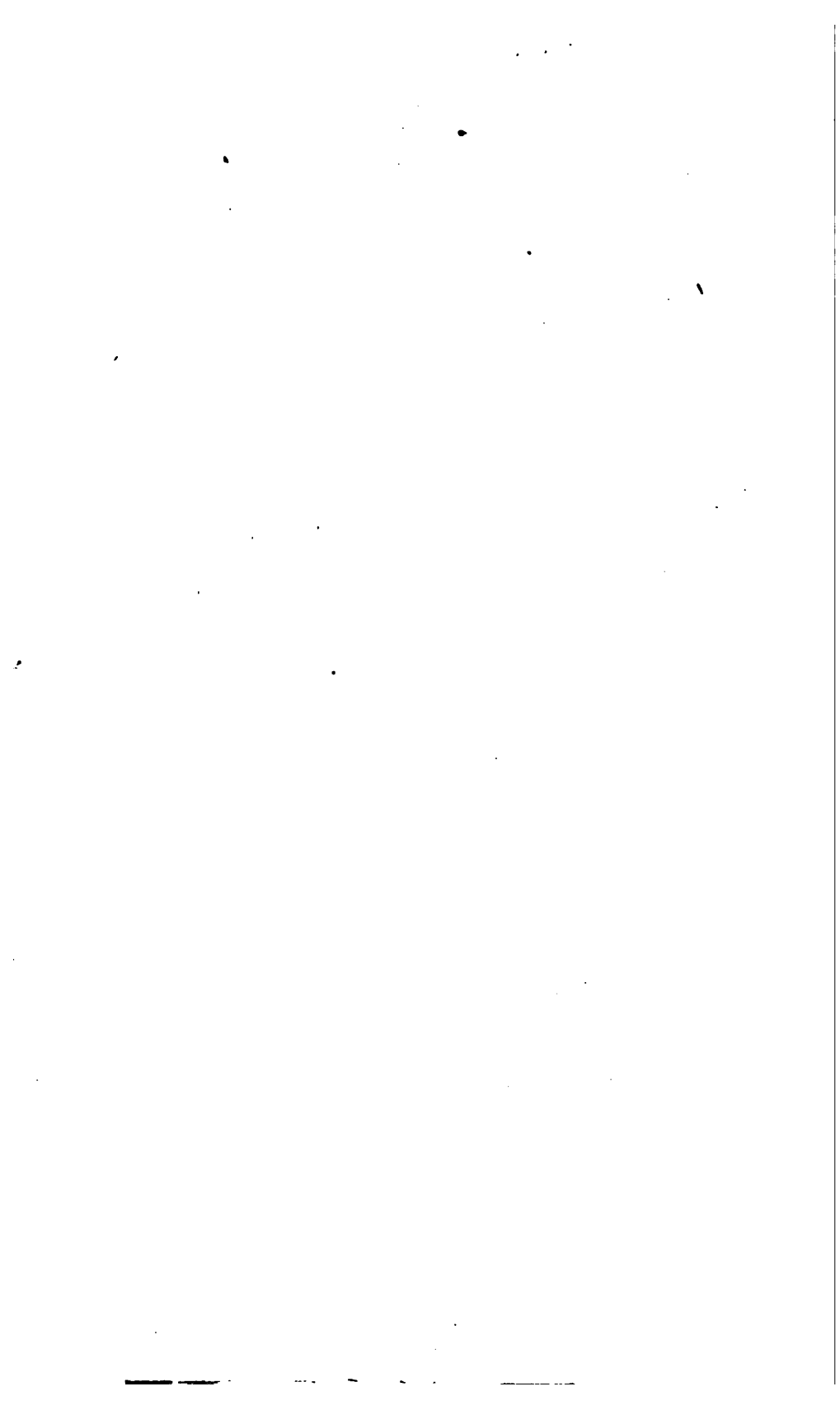
The United States Department of Agriculture gave the per capita consumption of wheat in 1910 as 5.31 bushels. Assuming the population to be one hundred million, the wheat requirement would be five hundred thirty-one million bushels. Allowing a milling yield of 68 percent of flour, would give 40.8 pounds of flour per bushel of wheat, or a total of 110,534,694 barrels. This figure will be used for these deductions as it is about the average percent of flour secured from the No. 2 Northern (Minnesota grades) wheat samples received from the 1916 crop. If it should be necessary to use as high a blend as 15 percent of barley flour milled as Lot 1, then 224,178,176 bushels of barley would be required. If milled as Lot 2, then 98,790,383 bushels of barley would be sufficient.

Market quotations at Chicago, Ill., for the week ending Sept. 29th, 1917, are reported on page 542 of the Northwestern Miller issued Oct. 3rd, as follows:—No. 3 Northern (Federal grades) Wheat \$2.14 per bushel; barley, \$1.165, Straight flour \$10.35 per barrel, mill feed \$1.77 per 100 pounds. Using these values for wheat and mill products a bushel of wheat yielding 68 percent of flour would give mill products valued at \$2.49 per bushel and a gross gain for manufacture over the cost of the wheat of 35 cents per bushel.

Allowing 35 cents as the cost per bushel for the manufacture of barley into flour and the following arbitrary prices for the by products from the barley, as shown in Table IV, hulls 50 cents per 100 pounds, other offal \$1.50 per 100 pounds, would give a cost price for the barley flour from Lot 1 of \$7.964 per 100 pounds; and for Lot 2 of \$4.333 per 100 pounds.

Therefore, the flour requirement for a year manufactured from No. 3 Northern wheat giving a yield of 68 percent of flour at \$10.35 per barrel would cost \$1,144,034,082.90. Manufactured from 85 percent of wheat and 15 percent of barley milled as Lot 1 it would cost \$1,231,245,956.47 or \$87,211,873.57 more by using the barley and would reduce the amount of wheat required 79,650,000 bushels. Manufactured from 85 percent of wheat and 15 percent of barley milled as Lot 2, it would cost \$1,113,244,643.01 or \$30,789,439.01 less by using the barley and would reduce the wheat requirement 79,650,000 bushels.

According to the above figures, it would be possible to use an amount of barley flour that would produce a loaf of bread very little below the quality of bread made from all wheat flour and at less cost than if made from all wheat flour.



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North Dakota Agricultural Experiment Station

Soil Survey of Bottineau County

North Dakota Agricultural Experiment Station
U. S. Department of Agriculture and
Bottineau County Cooperating

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SOIL SURVEY OF BOTTINEAU COUNTY*

By R. C. Doneghue

Bottineau county is situated in the north central part of North Dakota the northern line of the county being the International Boundary. The area of the county is 1,075,840 acres or 1,681 square miles.

There are two general types of topography in the county. The comparatively level to gentle undulating Prairie-Plains cover the greater part of the county and the rolling Turtle Mountains the northeast corner. The level areas of the Prairie-Plains are broken by a morainic region northeast of Souris, a small rolling area 5 or 6 miles west of Bottineau and small depressions and eroded areas adjacent to the streams. Numerous depressions are found in the Turtle Mountains. Some of these are filled with water making quite large lakes while others are more or less swampy and maintain a heavy growth of slough grasses.

The general elevation of the Turtle Mountain region is from 400 to 600 feet above the surrounding plain. They are from 2,000 to 2,100 feet above sea level. St. Paul Butte and Bear Butte are 2,300 feet and 2,200 feet respectively above sea level.

The general slope of the county is south and southeast although the Mouse River flows north. In the eastern part of the county the elevation of Bottineau is 1,644 feet above sea level. Willow City has an elevation of 1,478 feet. Nearer the river in the north central part of the county, Souris and Westhope have elevations of 1,520 and 1,506 feet respectively. Newburg and Deep south of the above mentioned towns have elevations of 1,472 and 1,458 feet. The western half of the county slopes eastward. Lansford in the southwest corner of the county is 1,613 feet above sea level and Antler in the northwest has an elevation of 1,542 feet.

There are numerous depressions without outlet and several large flat areas that are only partially connected with the drainage system of the county. The main drainage of the county is effected through the Mouse River. The flood plain lies about 50 feet below the surrounding country and the valley has many of the characteristics of a huge canal. The banks are quite precipitous and straight with few draws running back in the prairies. The length of the river in the county is about 30 miles and the fall is so slight that formerly the river meandered back and forth across the flood plain and had no well defined channel. A new channel has recently been dredged which makes the present water level 3 or 4 feet below the level of the surface of the soil of the river bottom which is now available for

*The soil survey of Bottineau county was made by the North Dakota Agricultural Experiment Station in co-operation with the Bureau of Soils of the U. S. Department of Agriculture. The field work was done by Melvin Thomas, A. C. Anderson and Murray Stebbins under the supervision of R. C. Doneghue of the North Dakota Agricultural Experiment Station and W. B. Cobb, W. I. Watkins and A. T. Strahorn of the Bureau of Soils. The chemical analyses were made by J. W. Ince of the North Dakota Experiment Station.

agricultural purposes. The southeastern corner of the county is drained by Willow Creek which has very little fall from where it enters the county south of Overly to where it leaves west of Willow City. Willow Creek is intermittent as are all other tributaries to the Mouse River within the county. There is very seldom any running water in its channel but pools of standing water are common. Oak Creek has its source in the Turtle Mountains, from which it flows south and joins Willow Creek just before it leaves the county. It comes down from near the central part of the mountains through a series of small lakes and meadows but it drains a strip only a few rods wide along its channel and receives some of the run off from the outer edge of the mountains through small tributaries. Boundary Creek begins along the western edge of the Turtle Mountains and flows approximately southwest to the northwest part of Starbuck township, where it turns northwest and enters the Mouse River. Stone Creek begins in the Turtle Mountains northwest of Bottineau and east of Carbury. It flows south and west and joins the Mouse River west of Kramer. It traverses the large body of heavy lake bottom soils which it incompletely drains as the fall is very slight and tributaries are few.

The main streams west of the Mouse River are Antler Creek and Cut Bank Creek. These creeks run in a southeasterly direction usually turning north shortly before entering the river. Antler Creek runs approximately along the International Boundary and drains the adjacent country. Cut Bank Creek enters the county in the southwest corner of Wheaton Township and joins the Mouse River just east of Deep after having swung south into McHenry County. In addition to these main tributaries of the Mouse River there are numerous small stream channels, sloughs, and drainage way depressions tributary to them. Numerous potholes and several lakes afford drainage for the fields immediately surrounding them. Considering the relatively scant amount of rainfall the drainage of Bottineau County is in most localities sufficient although it is far from complete.

CLIMATE.

The climate of Bottineau County is subhumid with comparatively long winters and short cool summers. During the winter months the temperature occasionally gets as low as 50° F. but the dry atmosphere causes the cold to be less penetrating than in more humid regions and the climate though somewhat vigorous is by no means excessively so. During July and August the temperature occasionally reaches 100° F. but that period is usually very short and the nights are always cool.

The following data, taken from the records of the Weather Bureau station at Willow City, except for the northeast corner occupied by the Turtle Mountains, are typical of Bottineau County.

The table shows this to be a region of rather light rainfall, but normally about 75 percent of the precipitation comes during the growing season. This makes it possible to produce as good crops here as in regions where the annual rainfall is much greater but is less favorably distributed.

TABLE I. MONTHLY, SEASONAL AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Temperature			Precipitation			
	Mean	Absolute maximum*	Absolute minimum†	Mean	Total amount for the driest year (1897)	Total amount for the wettest year (1908)	Snow, average depth
	°F	°F	°F	Inches	Inches	Inches	Inches
December	10.0	50	-37	0.37	0	0.46	3.4
January	1.7	48	-52	0.37	T	T	1.8
February	3.7	56	-54	1.42	0.40	1.40	5.1
Winter	5.1	56	-54	1.1	0.40	1.86	10.3
March	16.6	65	-45	0.80	0.85	0.80	3.0
April	40.2	88	-22	0.89	0.68	1.80	1.8
May	32.3	95	10	1.87	0.58	1.53	0
Spring	36.4	95	-45	3.56	2.09	3.93	4.6
June	61.4	96	28	3.70	1.17	6.80	0
July	65.9	101	30	2.21	2.77	2.50	0
August	64.1	104	27	1.86	0.45	3.10	0
Summer	63.8	104	27	7.77	4.39	11.90	0
September	54.3	101	11	1.73	0.34	0.58	1.0
October	42.2	87	-2	0.68	0.52	0.62	0.5
November	20.7	75	-30	0.45	0.42	0.47	5.9
Fall	39.1	101	-30	2.84	1.28	1.87	7.4
Year	36.1	104	-54	15.33	8.16	19.36	22.8

*Highest temperature recorded.

†Lowest temperature recorded.

The average date of the last killing frost in the spring is May 20th and the first in the fall is September 11th. The date of the latest frost recorded at Willow City in the spring is June 4th and of the earliest in the fall is August 20th. The average growing season between killing frosts varies from about 95 days in the more elevated northern parts of the county to approximately 104 days in the lower southern part.

The fall, winter and spring months are usually rather windy and occasionally hot winds damage the crops in summer. Hail occasionally damages the crops but on the average the aggregate of the damage done to the crop of the county comprises but a small percentage of the total acreage. The snowfall is comparatively light and the ground which freezes to a depth of from 4 to 6 feet is frequently bare during the winter months.

The rainfall in the Turtle Mountains is said to be greater than that in the rest of the county. Although no records have been kept the fact that crop failures due to drought are unusual in the mountain region would seem to substantiate this opinion.

SOILS.

The soils of Bottineau County have been derived from glacial drift. Much of this remains in nearly the same position as when it was deposited when the great ice sheet melted. It has been reworked to a considerable extent in some parts of the county. A considerable portion of the county lies within the region known to geologists as Glacial Lake Souris and some of the soils show evidence of lacustrine origin. There are no well defined beaches and the areas in which these soils are found are somewhat irregular. The fact that many of the soils are sandy in texture indicates that they were deposited by running water flowing from the melting glacier. The large amount of gravel along some of the small streams indicate that the soils of that region were formed by torrential glacial streams. The fine textured soils in the vicinity of Souris and Gardena were probably deposited from the quiet water of glacial lakes. The glacial drift and the material deposited by water in lakes and streams have been changed somewhat by weathering and the accumulation of organic matter. Three groups of soils or soil provinces are found in Bottineau County.

1. UPLAND SOILS.

The upland soils which occupy the greater part of the county are classified in the Glacial Province. Typically these soils have been formed by the weathering of unmodified glacial drift. Boulders are present but not usually abundant enough to interfere with cultivation. In this county some of the soils which have been reworked to some extent have been placed in this province because of their close similarity to those formed from the unmodified drift. These are free from gravel and boulders. The soils of this province have been further subdivided into the Barnes and Williams series. The Valentin fine sand in this county is also essentially an upland soil.

2. BENCH LAND AND LAKE BOTTOM SOILS.

The bench land and lake bottom soils which occupy glacial terraces and lake basins are classified in the Glacial Lake and River Terrace province. The soils of the Sioux, Fargo, Rogers, and Map series belong to this group.

3. THE BOTTOM LAND SOILS.

The bottom land soils which occupy the flood plain of the streams belong in the River Flood Plains province.

The relative area of the soils in the several groups is indicated in Table II.

BARNES SILT LOAM.

The Barnes Silt loam is uniform in texture to a depth of 10 to 15 inches with an average depth of 14 inches. The color varies from brown to black but is usually a dark brown. The organic matter content is very high. The soil pulverizes easily, does not crack on drying out and is not hard to cultivate.

Some gravel is found on the surface and is intermingled with the soil and subsoil throughout the soil column. Occasional boulders are found over most of the type especially near the Mouse River in the Eidsvold Township region. Much of this area and much of the

TABLE II. SOIL TYPES OF BOTTINEAU COUNTY

Soil type	Area		
	Sq. miles	Acres	Percent of total
Upland soils			
Barnes loam	468.8	300,032	27.9
Barnes loam—stone free phase	42.7	27,328	2.5
Barnes loam—heavy subsoil phase	34.6	22,144	2.1
Barnes very fine sandy loam	114.3	73,152	6.8
Barnes very fine sandy loam—stone free phase	256.0	165,840	15.2
Barnes fine sandy loam	116.9	74,816	7.0
Barnes fine sandy loam—stone free phase	77.9	49,856	4.6
Barnes silt loam	76.6	49,024	4.5
Barnes silt loam—stone free phase	63.4	40,576	3.8
Barnes clay loam	68.5	43,840	4.1
Barnes clay	3.8	2,432	.2
Williams loam—rolling phase	26.8	17,152	1.6
Williams sandy loam—rolling phase	4.0	2,560	.2
Williams gravelly loam	15.0	9,600	.9
Valentine fine sand	20.6	13,184	1.2
Bench land and lake bottom soils			
Fargo clay	93.2	59,648	5.5
Fargo silty clay loam	65.5	41,920	3.9
Rogers clay loam	4.7	3,008	.3
Peat and muck	12.7	8,128	.8
Maple clay loam	15.2	9,728	.9
Sioux loam	28.0	17,920	1.7
Sioux sandy loam	25.8	16,512	1.5
Sioux gravelly loam	11.4	7,296	.7
Bottom land soils			
Lamoure clay	21.6	13,824	1.3
Lamoure silt loam	1.4	896	.1
Lamoure fine sandy loam	11.6	7,424	.7
Total.....	1,681.0	1,075,840	100.0

type mapped east of there is finer in texture than the typical silt loam, approaching a silty clay loam.

At 14 inches the soil generally grades thru a light brown into a grayish yellow at 20 to 36 inches. The texture usually becomes a silty clay loam at 14 inches. From 30 to 26 inches the texture varies from a silt loam to a silty clay loam, being usually a heavy silt loam. Where the Barnes silt loam is associated with the Barnes very fine sandy loam the subsoil is coarser in texture and approaches a very fine sandy loam. The subsoil contains considerable lime.

The topography varies from level to gently undulating. It generally occurs at elevations slightly lower than the Barnes loam and in places especially in the smaller enclosed areas the soil texture is slightly affected by deposition by water. The topography is entirely constructional. The type is derived from glacial till and consists of typically unassorted material.

It has no definite drainage system but the drainage is usually sufficient to take care of the rainfall.

Practically all of the type is cultivated. It is one of the most desirable soil types in the region. All crops adapted to the region do well on this type. This is usually a slightly more productive soil

than the Barnes loam. A little larger proportion of the farm can be devoted to grain production on the Barnes silt loam. A rotation of

corn or potatoes 1 year,
wheat 1 year,
oats or barley 1 year,
hay 1 year,
pasture 1 year,
flax 1 year,
wheat 1 year,

—would be suited to this type. A mixture of grasses and a little alfalfa should give good results as a hay crop. Brome-grass, rye-grass and timothy would make a good grass mixture in this rotation. This is a good alfalfa soil.

BARNES SILT LOAM—STONE FREE PHASE.

The stone free phase of the Barnes silt loam is a dark grayish brown or black silt loam from 8 to 18 inches deep. The average depth of the surface soil is about 15 inches. Occasionally the texture is a little coarser than typical silt loam due to the presence of a considerable amount of very fine sand, and where areas of the type border on the Fargo clay or silty clay loam the surface soil is a rather heavy silt loam. The texture of the subsoil is usually the same as that of the surface soil or slightly more silty. The color of the subsoil is typically brownish or yellowish gray to gray although slight variations from these colors are frequently encountered. In some instances just below the layer of dark colored surface soil there is brown silt loam which passes into a light gray silt loam to silt from 22 to 28 inches below the surface. When wet the lower subsoil is frequently light yellow in color but on drying it becomes gray. The subsoil is generally friable in structure, but in some slightly depressed areas, there is a compact layer just below the surface soil which approaches a silty clay loam in texture. This compact layer is brownish in color and is usually about 6 inches in thickness. The subsoil below this is a brownish gray or gray silt loam. The extent of this variation of the type is small and such areas as do occur usually cover a few acres within larger typical areas of the type. Ordinarily the subsoil is more silty than the surface soil but in some areas associated with the stone free phase of the Barnes very fine sandy loam which is more undulating in topography than the majority of the type the subsoil contains a high percent of very fine sand. The surface soil is usually slightly calcareous and the subsoil is always markedly so. The topography is gently undulating. The drainage is sufficient although most of the rainfall soaks into the soil. There are no gravel and boulders present. By far the greater part of the type is under cultivation and average crop yields are as good as those on any other soil in the county. The rotation outlined for the typical phase of the Barnes silt loam is suited to this phase.

BARNES LOAM.

The Barnes loam is a dark brown loam to an average depth of 8 or 9 inches. The texture varies from a light loam to a silty rather heavy loam with a high organic matter content. In most cases it contains a high percentage of very fine sand. The subsoil is usually

slightly finer in texture especially in a layer occurring at about 15 or 20 inches. It grades into a slightly yellowish brown at about 9 inches and turns into a very light slightly yellowish gray at varying depths but usually at about 20 inches. The color of the subsoil varies with the moisture content becoming yellow when wet. The substratum at depths below 20 feet is blue clay.

In the northwestern corner of the county much of the type mapped is rather coarse in texture being closely associated with the Barnes very fine sandy loam of that region. A finer textured phase occurs in Cut Bank Township. More than the usual amount of gravel occurs over much of the type mapped in Scandia and Haram Townships (163-77 and 78.)

This soil is easy to cultivate and does not bake or crack on drying. The lime content is unusually high in the subsoil which gives it a light color and well granulated rather floury structure. Small reddish iron specks are frequently found thruout the subsoil. Boulders are commonly scattered over the surface of the type especially in the western part of the county, but are not usually present in sufficient quantities to seriously interfere with cultivation. The stone and gravel content consists of crystalline rocks, granite, gniess, schist and dark colored eruptives and limestone. A considerable percentage of the small stone content is limestone. All stones that have been imbedded in the soil are ingrusted with lime.

Most of this type has no definite drainage system but it is usually sufficient to take care of the rainfall. It is quite free from alkali. The topography is usually gently undulating being about level in places. An exception to this is a limited area northwest of Carbury which is quite rolling. Practically all of the type is utilized for agricultural purposes. Approximately 90 percent of it is cultivated at present and practically all can be tilled.

This is a productive soil and is well suited to general farming. It will hold the greater part of the rainfall which if properly utilized will produce good crops. This can be accomplished by growing crops in a well planned rotation. Such a rotation system should consist of a cultivated or intertilled crop and a grass or legume crop in addition to the small grains. A rotation of

corn or potatoes 1 year,
wheat 1 year,
oats 1 year,
grass 1 year,
pasture 1 year,
flax 1 year,

could be followed on many farms on this type. The manure could be used as top dressing for the pasture or plowed under for corn. Alfalfa can be grown successfully on this type and should have a place in the cropping plan. When a stand has been obtained it should be left down for at least 6 years. It can be left for a longer period but the soil where the alfalfa has been grown is improved for the growing of other crops and it is a good plan to put this land into the rotation and seed another field to alfalfa. Where alfalfa seed is the principal source of income it may be advisable to leave the land

in alfalfa for a longer period. Another rotation that would be suited to some farms on this type is as follows:

corn 1 year,
wheat 1 year,
oats or barley 1 year,
hog millet 1 year,

Alfalfa could be grown on one field for 4 or 8 years and then plowed up and the field placed in the regular rotation, another field being seeded to alfalfa. Brome-grass can be used as a pasture for several years and then plowed up and the field placed in the regular cropping system, another field being used for pasture.

BARNES LOAM—STONE FREE PHASE.

The surface soil of this type is a dark grayish brown loam from 8 to 20 inches deep. In slightly elevated undulating areas the type may contain a high percent of very fine sand and should be described as a light loam while in depressed areas the soils are frequently a little heavy. The subsoil to a depth of 36 inches is a yellowish or brownish gray loam to silt loam. The more level areas are silty and gray in the subsoil except for a few small areas which are depressional and receive seepage from higher lying types. These latter mentioned areas usually have dark brown rather compact silty subsoils. The more elevated undulating areas, those associated with the stone free phase of the Barnes very fine sandy loam and silty loam usually have light loam subsoil and are grayish brown in color.

Where this type is sufficiently well drained it is well suited to the production of small grain. To secure the best results they should be grown in a rotation with corn and some hay crop. Alfalfa would give a good yield of hay and help to maintain the fertility of the soil and improve the physical structure. A rotation of

corn or potatoes 1 year,
wheat 1 year,
barley or oats 1 year,
hay 1 year,
pasture 1 year,
flax 1 year, and
wheat 1 year,—

should give good results on this type. Timothy, western rye-grass or brome-grass could be seeded with the oats or barley for hay the following year. A mixture of these grasses might be advisable under some conditions and in some of the poorly drained areas an admixture of red top would help to thicken the stand. The topography is usually gently undulating although a few level areas occur. Drainage is sufficient except in a few depressed areas. The type was evidently deposited by glacial waters, either in the form of shallow lakes or moving waters from the melting ice. The type is free from gravel or boulders.

BARNES VERY FINE SANDY LOAM.

The Barnes very fine sandy loam is usually a dark slightly grayish brown very fine sandy loam to 8 or 18 inches with an average depth of about 12 inches. It appears quite black when in a moist condition due to the high organic matter content. A slight sprinkling of gravel is found on the surface and some stone is always found. The

upper subsoil is brown. It grades into a grayish yellow or yellowish gray calcareous very fine sandy loam at about 20 inches, the depth varying with the thickness of the surface layer. Below this the subsoil is almost a pure silt. The subsoil becomes distinctly yellow when moist and turns to a light gray when dry. It is quite retentive of moisture. The subsoil is fairly compact. Both the soil and subsoil are very smooth and even textured and have a floury, velvety structure when dry but become quite sticky when wet. The subsoil is not stratified and consists of unassorted fine and coarse material. A few gravel are present throughout the soil column.

The topography is usually undulating. Drainage is good. The type is derived from glacial till most of which has not been materially modified since its deposition. Some areas evidently have been affected by wind action judging by the extreme uniformity and fineness of the material and by the comparative absence of gravel and boulders. Many such small bodies are scattered over the country notably around Whitby Township and some of the areas skirting the Mouse River bottom on the east. This type is considered a productive soil. During favorable seasons it produces yields which compare very favorably with other soil types of the county but crops suffer from drouth more than on the heavier types in extremely dry years. It is regarded as being especially well adapted to intertilled crops such as corn and potatoes.

The same cropping systems as outlined for the Barnes loam would be suited to this type. A rotation of

corn or potatoes 1 year,
wheat 1 year,
winter rye, 1 year,
oats 1 year,

—with a fifth field in alfalfa which would be worked into the rotation every 4 or 8 years, would be suited to many farms on this type. A sixth field in brome-grass pasture could be worked in the same as the alfalfa. Another rotation that could be followed would be

corn or potatoes 1 year,
wheat 1 year,
hay 1 year,
pasture 1 year,
wheat 1 year,
oats 1 year.

BARNES VERY FINE SANDY LOAM—STONE FREE PHASE.

This phase of the Barnes very fine sandy loam to an average depth of 12 or 14 inches is a dark grayish brown very fine sandy loam. The dark colored surface soil varies in depth from 6 or 8 inches to 24 inches or more. In some areas the surface soil is fine textured approaching a silt loam. The subsoil to a depth of 36 inches is usually a yellowish gray very fine sandy loam. This is more especially true when the layer of surface soil is of maximum depth and probably represents a less well aerated condition than the more yellow subsoil phase of the type. Frequently a gray layer is encountered just beneath the surface soil which grades into a yellowish gray or even pale yellow very fine sandy loam containing a high percent of silt. This yellow subsoil usually becomes light gray on drying. Some

small areas west of Gardena have brown rather than yellowish gray subsoils. The subsoil nearly always contains a high percent of silt and has a characteristic friable structure. A few small depressions were mapped within larger areas of the stone free phase of the Barnes very fine sandy loam which have a very fine sandy loam surface soil underlain by a very fine sandy clay or silty clay loam subsoil which is yellowish or brownish gray in color. Areas of this variation of the type occur chiefly in the southeast part of the county. Some depressed areas occur in which the color and texture of the soil differs very little from that of the more extensive areas of the type. It is free from gravel or boulders. The material composing the soil was evidently sorted out and deposited by glacial waters. The most plausible explanation of the deposition of this soil material is that the ice sheet above these areas of soil bore large quantities of very fine sand and still finer material. The ice melted very rapidly, the water depositing the greater part of the sand and a good deal of the silt before it sought the slightly lower levels and became stationary. The finer materials, the clays and the greater part of the silts, were then deposited more slowly. The original material was probably fine sandstones and shales.

This type is easy to cultivate and the topography is sufficiently uniform to permit cultivation of probably 95 to 100 percent of the type. The same cropping can be followed on this type as on the typical Barnes very fine sandy loam.

BARNES FINE SANDY LOAM.

The greater proportion of the Barnes fine sandy loam is a medium dark grayish brown fine sandy loam to 7 to 20 inches deep. This type as mapped east of the Mouse River differs considerably from the type mapped west of the river. The phase mapped east of the Mouse River has a dark layer of an average depth of about 8 inches, below which it grades through a light brown into a yellowish gray fine sandy loam. The soil and subsoil of this phase contains a high percentage of coarse sand and gravel often approaching a sandy or gravelly loam and includes some small bodies of sandy loam. Boulders are common on this phase. It generally has a rolling topography.

The Barnes fine sandy loam mapped in the western part of the county is mostly a fine sandy loam to an average depth of about 12 inches or more. It usually has a smooth even texture although it varies from a fine textured very fine sand to almost a loam. Much of it approaches the lighter phase of the Barnes loam in texture. The soil has a fairly high organic matter content and is quite free from gravel and boulders. The subsoil grades through a brown fine sandy loam into a grayish yellow, which occurs below 20 inches. It has an undulating to level topography.

The subsoil of the Barnes very fine sandy loam is highly calcareous. It is loose and incoherent in structure.

The subsoil is not very retentive of moisture although it retains the greater part of the rain-fall. Most of the type is naturally well drained but there is practically no surface runoff. The moisture is absorbed by the soil and any excess escapes by percolation. Most

of the type is evidently derived from unmodified glacial till. The type has been very slightly affected by wind action. The more even textured areas have to be handled very carefully to prevent drifting.

This soil is inclined to be drouthy but in favorable seasons it produces very good yields. It is regarded as being especially well adapted to intertilled crops.

A rotation of

corn 1 year,
durum wheat 1 year
winter rye 1 year, and
sweet clover 1 year,

with a fifth field in alfalfa to be put in the rotation every four or eight years should work out well on this type. If the soil is inclined to drift the corn ground could be given a light covering of manure after the crop has been cut. The following spring it would be seeded to wheat without plowing. After the wheat crop is removed in the fall, winter rye can be seeded in the stubble. Early the following spring, sweet clover would be seeded with the rye. The following year the sweet clover crop could be cut for hay or seed. The next year it could be plowed and planted to corn again. Under this system the land would be plowed but once in 4 years and the soil would be protected from drifting during the winter and spring. The soil would be fairly compact and should produce good crops.

BARNES FINE SANDY LOAM—STONE FREE PHASE.

The surface soil of this type is a dark gray to almost black fine sandy loam or light fine sandy loam from 8 to 20 inches in depth. The average depth of the dark layer is about 14 inches. There is very seldom an abrupt change in color. The upper subsoil is a medium dark gray shading into a gray or light gray color in the lower layers. The texture to 30 inches is a fine sandy loam. Below this depth the subsoil is usually a heavy fine sandy loam or clayey fine sandy loam which varies from gray to drab in color. This heavier layer is not always encountered within the three foot section. The type is usually free from gravel and boulders. Some fine gravel occurs in spots in some of the areas in the eastern part of the county and in the areas south of Maxbass. A few small areas of sandy loam were included with this type. Such areas occur near Lords Lake in the eastern part of the county southwest of Bottineau, and south of Maxbass. The topography as a whole is from level to gently undulating. It is usually a little lower elevation than the stone free phase of the Barnes very fine sandy loam. The material seems to have been deposited by sheets of glacial waters as they flowed from the melting ice into Glacial Lake Souris.

This type is not as productive as the stone free phase of the Barnes very fine sandy loam but is a good corn, potato and alfalfa soil. Oats, durum wheat and winter rye, should have a place in the cropping system. This type is so nearly level that all the rainfall which does not evaporate soaks into the soil. The fine textured material in the lower subsoil helps to retain a good proportion of this water within reach of crop roots.

BARNES CLAY LOAM.

The surface soil of the Barnes clay loam is a black or dark grayish brown clay loam from 6 to 18 inches in depth. The shallower surface soil occurs on small hill tops and the deeper layer of black clay loam occurs in depressions. The usual depth of the surface soil is 10 inches. The subsoil to a depth of 3 feet is a brownish to yellowish gray clay loam to clay which sometimes contains loamy or sandy pockets and occasionally a distinct layer of coarser textured subsoil is encountered at about 26 inches. This coarse layer is of the same color as the clay loam or clay subsoil and is usually a loam in texture. Boulders are common on the surface and gravel may be encountered anywhere within the three foot section. Some areas occur in which there is almost no gravel and which are free from boulders. These are usually slightly finer in the texture of both the soil and subsoil than the more typical areas of the type. The type is derived from the weathering of glacial till.

The clay of this type seems to come from the weathering of diabases and limestone and from shale scraped from the northern edge of the mountains and deposited along with other material where the heavy types of Turtle Mountain soil are now located.

The topography is from undulating to rolling. The elevations are not in the form of ridges and there are almost no longitudinal valleys. The surface of the type is made up of numerous small elevations and depressions which have no outlets. The depressions are frequently occupied by small lakes or peaty meadows that occupy the beds of drying up or dried up lakes and ponds. That part of the rainfall which does not soak into the soil drains into these depressions. The greater part of the rainfall, however, is retained by the soil which makes an unusually good reservoir for moisture on account of its fine texture and its high organic matter content. The uncultivated areas of the type are practically all timbered. Owing to the character of the soil and vegetation, to the presence of lakes and to the fact that probably the rainfall is greater on the type than on the prairie soils crop failures due to drouth seldom occur. This is true also of other soil types within the Turtle Mountains. The Barnes clay loam is the most extensive type within the Turtle Mountains and does not occur elsewhere within the area. The tree growth on the type consists of poplars, oaks, birches, willows, and several varieties of shrubs are common. About 20 percent of the type is in cultivation at the present time and eventually the greater part of the type will be cleared and farmed.

It has been found that any crop adapted to Bottineau County will grow well on the Barnes clay loam. It is stated that the wheat produced on this and other soil types which occur in the Turtle Mountains grades a little lower than that produced on the prairie. This is thought to be due to the more abundant rainfall in the Turtle Mountains which tends to make the wheat a little softer than wheat grown on the drier prairie soil types. This slightly inferior quality, however, is offset by higher average yields. Potatoes do well on the Barnes clay loam. Cattle are pastured in the woods and on the peaty meadows which occur throughout the type.

Rotations similar to those outlined for the Barnes clay are suited to this type.

BARNES CLAY.

The Barnes clay is usually a dark brownish drab to black clay 6 to 10 inches deep underlain by an olive drab or brownish gray heavy plastic clay. Some areas occur in which there is no variation in color or texture from the surface to a depth of 3 feet or more. However, the surface few inches is usually darker in color than the subsoil. The type is practically free from gravel and boulders, differing in this respect from the Barnes clay loam. The type occurs in the Turtle Mountains and is not very extensive although several areas of half a square mile or more were mapped. The topography is slightly undulating with some very nearly level areas. In spite of this the drainage is fairly good. Oak trees are a characteristic growth on uncultivated areas of the type. They are frequently more common than poplar. About 40 or 50 percent of the type is in cultivation.

This soil has a high water holding capacity and will stand heavier cropping to grain than some of the prairie soils. A rotation of

corn or potatoes 1 year
wheat 1 year,
oats 1 year,
barley 1 year,
clover and timothy 1 year,
flax 1 year,

could be practiced on this type. Another that could be followed is

corn or potatoes 1 year,
wheat 1 year,
oats and barley 1 year,
clover and timothy 1 year,
flax 1 year,
wheat 1 year,

Alfalfa could be grown to advantage on this type.

BARNES LOAM—HEAVY SUBSOIL PHASE.

Typically the heavy subsoil phase of the Barnes loam has a gray loam to silty loam surface from 8 to 14 inches in depth. Numerous areas occur, however, in which the soil is dark gray or medium dark brown in color, and in areas that are still in timber there is generally an inch or two of almost black loam on the surface, the soil beneath this being gray. The subsoil to a depth of 36 inches is a yellowish brown or dark yellowish gray clay loam to clay. Some areas occur in which the subsoil to a depth of 26 to 30 inches is a clay which contains a small amount of gravel and sand, below which a lighter layer is encountered. This layer is usually a light clay loam or loam in texture and contains some fine gravel. The structure of the subsoil is rather compact except for this lighter layer. Some boulders are generally present on the surface. The type occurs exclusively in the Turtle Mountains. Its topography is from undulating to rolling. The drainage is good. The numerous small lakes and meadows which occupy depressions scattered throughout the type are characteristic of this phase of the Barnes loam. Where large enough, the meadows were shown on the map as peat or muck, but a number of such meadows too small to map were included with this type. Only about 15 or 20 percent of the type is in cultivation at present. The re-

mainder supports a growth of small timber which consists mostly of poplars although a few birch, oak, wild cherry, and willow trees occur. A heavy crop of wild peas is found on all partly cleared areas. The land is being gradually cleared of timber and put in cultivation and eventually probably as much as 85 percent of the type will be available for agricultural purposes.

This is not as productive a soil as the Barnes clay and the Barnes clay loam but much the same crops can be grown and the cropping suited this type will be similar except that a smaller proportion of the farm can be used for grain production. This type is better suited for the production of corn, and potatoes than the finer textured types in the Mountains.

WILLIAMS LOAM—ROLLING PHASE.

The surface soil is a grayish brown or dark grayish brown loam. The depth of the soil is from 8 to 12 inches as a rule but may be only 5 or 6 inches where there is considerable erosion. The subsoil to a depth of 36 inches is a yellowish gray to light yellowish gray loam to silty loam which usually contains a small percent of gravel. The lime content of the subsoil is high. Stony areas too small to map have been included with the type and a few small boulders are nearly always present on the surface. Gravel is encountered in both soil and subsoil. The topography is rolling to hilly and the drainage is usually excessive. The larger areas of the type are located along the outer edges of the Turtle Mountains but smaller areas occur on eroded slopes along some parts of the Mouse River and some of its tributaries. The type is used almost exclusively for pasture. It is not cultivated on account of its hilly topography and excessive drainage. Clumps of scrub oak trees and wild rose bushes are common, especially along coulees and depressed areas.

WILLIAMS SANDY LOAM—ROLLING PHASE.

The Williams sandy loam is a gray to dark grayish brown loam usually about 10 inches deep. The subsoil is yellowish or brownish gray sandy loam containing some coarse sand and fine gravel. The subsoil frequently passes into a sticky sandy loam or sandy clay loam at about 20 to 26 inches. The type is generally covered with a growth of small timber. It is derived from glacial till. Boulders and gravel are usually present on the surface and a small amount of gravel is often encountered in the soil section. This type occurs on the Turtle Mountains and uncultivated areas are wooded. The topography is undulating to rolling. It is not valued as highly as the Barnes clay loam and loam associated with it as it has a lower water holding capacity and crops suffer in drouthy periods.

WILLIAMS GRAVELLY LOAM.

The Williams gravelly loam to a depth of from 6 to 10 inches is a brown or dark grayish loam or fine sandy loam containing 10 percent or more of gravel. The subsoil to a depth of 3 feet is a yellowish or brownish gray rather friable loam or fine sandy loam containing whitish streaks and a rather high percent of gravel. The content of gravel is somewhat higher in the areas occurring along the

border between the prairie and the Turtle Mountains than in areas occurring elsewhere in the county. These areas occurring along the edge of the mountains are rather gently sloping while those occurring in other parts of the area are usually rolling in topography. Boulders are common on the surface. The Williams gravelly loam represents, where it occurs along streams, areas of Williams loam or fine sandy loam areas which have been rather extensively eroded thus concentrating the gravel which is usually present in small amounts in soils of the Williams series. Some areas of the Williams gravelly loam are cultivated, but crop yields are rather low and the greater part of it is better suited for pasture than for cropping. One phase of the Williams gravelly loam consists of a dark grayish brown gravelly fine sandy loam to a depth of 4 to 5 inches. The subsoil is made up of sand, fine sand, and gravel together with some heavier layers and is usually more or less stratified. The gravel are usually from granite, gneiss, limestone, diorite, and sandstone, and quartzite fragments are frequently found. This phase usually occurs as knobs or kames. Extreme porosity of the subsoil and the sloping topography results in excessive drainage and it is of very little value agriculturally. The area of the phase in the county is very small. A few small areas occur in the east central part of the county.

VALENTINE FINE SAND.

The Valentine fine sand to a depth of about 20 inches is a brown or grayish brown fine sand to loamy fine sand. The organic matter content is not as high as in the sandy types of the Barnes series mapped in Bottineau County. The subsoil to a depth of 3 or more feet varies from a grayish brown to gray fine sand or loamy fine sand. Sometimes the difference in color between the surface soil and subsoil is very slight, and the transition from one to the other is very gradual. In some depressions occurring in that area of the type south-east of Eckman the surface soil is a fine or very fine sandy loam which passes at about 12 inches into a bright yellow fine or very fine sand. These areas were considered too small and of too limited extent to map out as a separate soil type. The surface of the type is billowy and numerous small wind formed hillocks occur. A few small areas are associated with the stone free phase of the Barnes fine sandy loam and very fine sandy loam. Where it borders the latter it is very nearly a very fine sand in texture.

The drainage is excessive owing to the drouthy subsoil. Only about 30 percent of the type is cultivated. Uncultivated areas have a characteristic growth of dwarf willows and numerous weeds and grasses. The Russian thistle has become a common growth on the type. Occasionally clumps of larger willows and shrubs grow in depressions. The lightness of the soil which tends to make it blow badly seriously affects the agricultural value of the type. Crops common to the region are grown and yields are somewhat below the average of the county. Some depressed areas in which drainage is less excessive produce a fair quality of native hay. A rotation of

corn or potatoes 1 year,
wheat 1 year,
winter rye 1 year,
sweet clover 1 year,

—would help to keep the soil from drifting. After the corn crop is removed in the fall the soil could be given a light covering of manure to check drifting during the winter and spring. In the spring the soil could be disked and seeded to durum wheat. Winter rye could be stubbled in that fall and sweet clover seeded early the following spring. If a stand is secured the land would be in sweet clover the year following the winter rye. The crop could be used for hay or seed. In the spring following the sweet clover the land could be plowed for corn. A light top-dressing of manure for the corn would help to check drifting. If alfalfa can be started on this soil it will produce fairly good crops. A light covering of manure immediately after seeding will help to check drifting while the young alfalfa is getting a start.

SIoux LOAM.

The Sioux loam to an average depth of about 10 inches is medium dark or dark grayish brown to a dark brown in color. It is usually a loam although it varies from a light loam to a heavy silt loam. At 10 inches it turns to a brownish color and at 15 inches to a brownish or yellowish gray, with layers of reddish brown. The subsurface from 10 to 24 inches is generally finer in texture than the soil. At depths varying from 16 to 36 inches or more occur beds of coarse alluvium consisting of stratified layers of coarse sand and gravel with considerable fine interstitial material to a very fine sandy gravelly loam. It is loose and incoherent in structure and non-retentive of moisture. The subsoil varies greatly. Many small areas of alluvial soils along Cut Bank Creek in which the gravel does not appear within 36 inches were included within the type as the area was insufficient to warrant the establishment of a new type.

Sioux loam was mostly mapped as narrow strips extending between the Barnes loam and very fine sandy loam in rather straight courses in the western part of the county. It is largely confined to gentle sloping terraces in swales bordering old drainage channels at elevations somewhat lower than the contiguous glacial types. The total area is relatively small. The drainage is usually excessive due to percolation and surface runoff. Due to its droughty nature the value of the soil for crop production is not as high as the Barnes loam. In the southwestern part of the county the Sioux loam and the contiguous type is often indefinite. About 75 percent of the type is cultivated at present. The crops common to the region are grown. A rotation of

corn 1 year,
wheat 1 year,
barley or oats 1 year, and
sweet clover 1 year,

could be followed on this type.

SIoux SANDY LOAM.

Sioux sandy loam is usually a medium dark grayish brown sandy loam 7 to 20 inches in depth with an average of 12 inches. A fine sandy loam to fine sand was included in the type. At 10 inches is usually a light brownish gray sandy loam, which contains considerable gravel and coarse sand, although it may be of a yellow

lowish gray or yellow color. Below 20 inches the texture is much coarser consisting of interbedded sand and gravel but mostly sand and is usually of a rusty brownish to dark red in color. Both the soil and subsoil are loose and incoherent in structure.

Sioux sandy loam occurs as small bodies scattered over the county with a relatively small total area. A considerable portion of the type occurs along Cut Bank Creek especially south of Maxbass. The type occurs along minor stream bottoms or terraces which are more elevated than the ones on which the Sioux loam occurs and usually slightly less elevated than the terraces on which the Sioux gravelly loam is found. The type consists of alluvial material derived from glacial till and was deposited during the glacial period. It is not inclined to blow badly except on small spots on the fine sandy phase of the type. Due to the porous nature of the subsoil the water holding capacity is poor. The water escapes by percolation rather than by runoff and the drainage is usually excessive. Owing to its drouthy nature the agricultural value is rather low. Probably 60 percent of the type has been cultivated but much of it has been allowed to go back to native grass. A rotation similar to that outlined for the Sioux loam should work out satisfactorily on this type.

SIoux GRAVELLY LOAM.

Sioux gravelly loam is a medium dark brown loam or sandy loam containing considerable gravel to an average depth of about 10 inches where it grades directly into beds of gravel and sand. A large number of very gravelly spots occur over the type. The subsoil consists of coarse alluvial sand and gravel well stratified with more or less intermingled fine material in some layers. It is usually reddish brown at about 10 inches and gradually merges to a brownish gray or light yellowish brown with many layers of a distinctly reddish hue. It is very loose and porous and has a poor water holding capacity. Considerable water is lost by percolation.

The type occurs as level elevated terraces bordering old water courses often at the junction of drainage channels. It was deposited by glacial streams when the melting ice produced great streams of water. It is somewhat dissected by erosion in places giving it an undulating appearance.

Only a very small part of the type is cultivated. Many fields formerly cultivated have been allowed to go back to grass. The large amount of gravel makes cultivation difficult which together with its drouthy nature render it unsuitable for crop production. It is covered with a fair growth of native grass and makes fair pasture for which it is largely utilized. It is also valued for the sand and gravel which it contains.

FARGO CLAY.

The Fargo clay to a depth of from 12 to 20 inches is a dark grayish brown, drab, or black clay. The content of organic matter is usually high and in areas that have never been cultivated there is usually a layer of dark brown peat from a half inch to an inch in thickness on the surface. The lime content is high. The soil is rather heavy and plastic and is difficult to cultivate although it is

easily tilled for a soil of this texture. If plowed in the fall it can be worked into a granular condition the following spring so that it is possible to make a good seed bed. The surface soil of the Fargo clay varies somewhat even in an area of uniform topography. The texture in some areas is a silty clay. Such areas occur within the larger areas of the type near Souris. Small inclosed areas also occur in which the dark colored surface layer is interrupted by a brownish gray layer of clay at about 6 inches which becomes dark again from 12 to 18 or 20 inches. In some areas east of Gardena there is a small amount of alkali present on the surface. Such areas also occur within the large area east of Willow City. The subsoil at a depth of 36 inches or more is gray to dark gray or drab heavy, compact clay. The transition from soil to subsoil is usually gradual. The color begins to get lighter at about 18 inches where it is usually dark gray in color. From this depth it becomes gradually lighter in color, passing through brownish gray to gray at about 30 inches. This is not always the case, however. Frequently the subsoil is uniformly dark or drab in color to a depth of 3 feet. In some cases a silty clay is encountered at about 31 inches, and in the large area of Fargo clay east of Willow City there are smaller areas in which a layer of silty loam or very fine sandy loam is encountered at from 30 to 40 inches. This layer is usually about 6 inches in thickness and is underlain by dark gray or grayish brown clay. The subsoil contains a high percent of lime.

The topography of the type is level and as there are very few streams passing through areas of the type it is poorly drained. Usually this does not seriously affect cultivation owing to the fact that the rainfall is not enough to require a very extensive drainage system. In a number of cases, however, it has been necessary to provide artificial drainage. The material composing the Fargo clay was deposited in the lower lying parts of its bed by the shallow quiet waters of the prehistoric Glacial Lake Souris. The type is free from gravel and boulders.

A rotation of
corn or potatoes 1 year,
wheat 1 year,
oats or barley 1 year,
grass 1 year,
flax 1 year, and
wheat 1 year,—

should work out on this type. If flax is not to be grown the rotation can be cut to 5 years. Potatoes might be substituted for corn on well drained land. A mixture of brome-grass, slender wheat-grass, and sweet clover should make a fair hay crop. In the wetter areas alsike and red top could be added to the mixture. Alfalfa will give good returns on the better drained areas.

FARGO SILTY CLAY LOAM.

The Fargo silty clay loam in typically developed areas is a dark grayish brown to black silty clay loam from 12 to 24 inches deep. Several small areas in different parts of the county are not typical. The surface 4 to 6 inches being a dark grayish brown to nearly black silt loam which passes into a clay of the same color which continues to a depth of from 12 to 20 inches. The surface soil is rich in or-

ganic matter and there is usually some lime present. The subsoil to a depth of 36 inches varies from a gray to medium dark grayish brown silty clay loam to clay or in some cases even a heavy silt loam. The areas with a gray silty subsoil occur north of Kramer in areas of the type closely associated with the Barnes silt loam and loam. This variation of the type may contain a small percent of gravel in the lower subsoil and probably represents till soil overlain by 2 feet or more of water deposited material. Except for these few areas the type is free from gravel. The topography usually is level. This type is closely associated with the Fargo clay and the stone free phase of the Barnes silt loam. It usually occupies a slightly higher elevation than the Fargo clay and is lower than the silt loam. The drainage of the type is poor but the rainfall is not sufficient to cause much damage to crops. Locally the type is included with the Fargo clay under the name "gumbo". However, it is considered a lighter phase of "gumbo" as cultivation is easier than on the Fargo clay. On account of its slightly higher position it produces better crops in wet seasons than the Fargo clay. It is better corn soil than the Fargo clay. The rotations suited to the Fargo clay can be followed on this type. The greater part of the type exclusive of numerous small depressional areas is cultivated. Hay is cut from the poorly drained depressions.

ROGERS CLAY LOAM.

The Rogers clay loam is a light grayish brown clay loam or silty clay for a depth of from 8 to 15 inches. The subsoil to a depth of 3 feet is a light gray, drab, or brownish or yellowish gray clay loam to clay which is very plastic and sticky and seldom dries out. Occasionally a very small percent of coarse sand is present in the subsoil below 30 inches. The type contains large quantities of alkali and in dry weather white bare spots can be seen on the surface.

The Rogers clay loam occurs as the beds of extinct lakes and ponds some of which have been varied by the acquisition of material from the higher lying surrounding types. The drainage is rather poor and the type is seldom cultivated. A few small areas have been cultivated and planted to grain as part of a field of some other type but the crops are noticeably poorer on the Rogers clay loam than on the associated type.

A coarse textured phase of this type is found in the south eastern part of the county. The surface soil of this phase is a gray to brownish gray very fine sandy loam from 8 to 12 inches in depth. There are usually indications of alkali on the surface. The subsoil to a depth of about 20 inches is a gray very fine sandy clay to clayey very fine sand or very fine sandy loam. Occasionally there is a concentration of clayey material just below the layer of surface soil, the subsoil 2 or 3 inches lower being coarser in texture. Below 20 inches the subsoil is a gray very fine sandy loam to clayey very fine sand mottled with yellow. When wet this lower subsoil has the appearance of being very sandy but upon drying out is hardened into cement like clods. The soil occurs in flat bottomed depressions and is poorly drained. This phase is not very extensive. It occurs chiefly

south of Willow City in the southeast corner of the county. A few small areas have been mapped in other parts of the county. The soil is not cultivated to any extent. It is used almost exclusively for hay and pasture.

MAPLE CLAY LOAM.

The Maple clay loam consists of a gray, dark gray or grayish brown clay loam to silty clay loam or heavy loam or silt loam, even fine sandy loam. The average depth of the darker layer of soil is about 8 inches although in some places the soil may be 18 inches deep. There is usually alkali present in the soil which makes it sticky and plastic and refractory. The surface few inches is usually fairly well supplied with organic matter. The subsoil is typically a gray or light drab clay loam to silty clay loam. Occasionally a small percentage of sand and fine gravel is present in the subsoil. Below the subsoil at depths varying from 18 inches to 2 feet or 30 inches from the surface is a substratum of sand or sand and gravel. Occasionally the transition from the heavy subsoil to the sandy substratum is gradual, a sandy clay being first encountered which gradually gives place to a sticky fine sandy loam or fine sand. Frequently layers of gray clay are present in the sandy substratum. Some areas have been mapped in which the subsoil passes into a gray and yellow mottled very fine sandy loam rather than the coarser sand material that is characteristic of the type. The gray color of both subsoil and substratum is frequently varied with brown and yellow mottlings.

The Maple clay loam is distributed throughout the county, yet its total area is small. It occurs chiefly as narrow strips in small drainage way depressions and some areas have been mapped in disconnected sloughs which were once evidently drainage channels. A few areas were mapped that were evidently the remnants of dried up ponds or small lakes. One such area occurs east of Souris.

In spite of the sandy substratum the drainage of the entire type is poor owing to the sticky character of the surface soil and the low position of the type which usually receives considerable drainage from adjacent land. This soaks into the light substratum which serves as a drainage channel helping to keep it more or less waterlogged in places.

The Maple clay loam as found in Bottineau County is not cultivated. It is usually used for pasture and occasionally hay is cut from it. Alkali or salt grass is a characteristic growth.

LaMOURE CLAY.

The LaMoure clay is a brown clay to a depth of about 18 inches. The color may vary to a grayish brown or medium dark brownish drab in places. A black peaty layer due to the accumulation of organic matter often occurs to a depth of 1 to 3 inches. The subsoil is usually a light brownish drab color although often a gray or slightly brownish gray of the same texture. Notwithstanding the fine texture and poor drainage the soil has a good structure and granulates well on drying. That is probably due to some extent to the high percentage of lime and to the fairly high organic matter content.

The subsoil is quite compact and is somewhat tenaceous. Red iron specks and small pockets of crystals are quite common in the subsoil. No stone or gravel occur.

The type consists of alluvium deposited by the sluggish stream of the Mouse River along the low flood plain. Before the bottom was recently drained by dredging a new deeper straight channel this soil was inundated a considerable part of the growing season but much of it was often dry enough during the haying season to allow the cutting of the heavy growth of marsh hay which it produced. In favorable seasons some patches yielded as high as 4 tons of hay per acre. Since it was drained the type has been more generally utilized most of it being now either pastured or cut for hay every year. The yields of hay probably average about $1\frac{1}{2}$ tons per acre. A limited area is under cultivation, flax being the principal crop at present. The general level of the type is about 4 to 6 feet above the river level. Drainage is not yet very well established and cultivated crops are apt to suffer from an excess of water in wet seasons. The water table is still rather high. It is gradually receding and eventually most of the type will probably be farmed. When the drainage has been accomplished this soil should produce good crops of alfalfa and small grain.

LaMOURE FINE SANDY LOAM.

The LaMoure fine sandy loam varies from a dark grayish brown fine sandy loam to very fine sandy loam or loam. These variations may occur as separate areas or as variations within the same area. The depth of the surface soil is from 10 to 18 inches. The surface soil is rich in organic matter. The subsoil to a depth of 3 feet or more is a brownish gray fine sandy loam, to loam which is noticeably calcareous. The type occurs as alluvial strips along streams. The topography is very nearly level except where abandoned stream channels are numerous. The drainage of the type is fairly good as the surface of the soil is usually elevated from 5 to 7 feet above the water level in the stream channels. The streams along which bodies of this soil lie are intermittent and contain flowing water only during unusually wet seasons. They very seldom if ever overflow their banks. Consequently the type is very seldom altered by the deposition of additional soil material. The soil is very productive, but the relatively small areas make the cultivation of large fields impractical so that the type is used principally for pasture and hay meadow. Occasional fields of flax and barley are grown. Farmers frequently plant their vegetable gardens on this type.

The surface soil of the heavy phase of the LaMoure fine sandy loam is a dark grayish brown or nearly black clay loam, 12 to 20 inches deep. The texture of the surface soil is not very uniform. Small patches of clay, loam, or fine sandy loam may occur and one or two areas of silty clay loam are found along Cut Bank Creek in the southeast part of the county have been included with the type. The subsoil is usually a gray clay loam which passes into a gray sandy loam at 24 to 30 inches. This sandy layer is usually underlain at 3 feet or more below the surface by a layer of brownish gray clay loam to clay. In some instances the sandy layer is not encountered within

3 feet. This phase occurs as alluvial flats along streams which very seldom overflow. It is used mostly for pasture, but a few fields have been cultivated with fairly good results.

LaMOURE SILT LOAM.

The surface of the LaMoure silt loam is a dark brownish gray or drab heavy silt loam for a depth of 8 inches. The subsoil to 36 inches is an olive drab silt loam to heavy silt loam. Uncultivated areas of the type usually have about 1 inch of brown or dark brown peaty material on the surface. The LaMoure silt loam occurs as flat bottom land along Antler Creek and as a few small areas in the bottom of the Mouse River. The more extensive area along Antler Creek very seldom overflows and is fairly well drained. The surface of the type is about 8 or 10 feet above the level of the water of the creek. About half of the type is in cultivation. It can be used in the production of the common crops of the county. The uncultivated part of the type is covered with a growth of small trees and shrubs.

PEAT AND MUCK.

Peat or muck as mapped in Bottineau County occurs chiefly in old lake beds in the Turtle Mountains. The surface 20 inches is a brown to dark brown loamy peat or muck containing in addition to a large amount of vegetable matter, fragments of the shells of numerous small water animals. The subsoil below 20 inches is a brown friable silty clay loam containing a high percent of organic matter. Bodies of this material varying in size from 1 to 20 or 30 acres occur throughout the Turtle Mountains and one or two areas were mapped on the prairie. Numerous areas occur which are too small to be shown on the map. Some areas occur which are marshy, but areas sufficiently dry to allow for the cutting of hay are far more extensive. The native grasses growing in the meadows occupied by peat or muck make a good quality of prairie hay.

THE CHEMICAL COMPOSITION OF THE SOILS OF BOTTINEAU COUNTY.

Typical areas of the respective soil types were selected and samples taken from each for chemical analysis. The samples were taken at three depths, the surface 7 inches representing the plowed layer, 7 to 18 inches the subsurface and 18 to 40 inches the subsoil. Composite samples of each depth were made for each of the more im-

TABLE III. CHEMICAL COMPOSITION OF THE BARNES LOAM IN BOTTINEAU COUNTY, NORTH DAKOTA. COMPOSITE OF 17 SAMPLES

	Surface soil 0-7 inches per acre	Subsurface 7-18 inches per acre	Subsoil 18-40 inches per acre
	Pounds	Pounds	Pounds
Total phosphorus	1,194	2,148	3,048
Total nitrogen	5,590	6,080	4,086
Total potassium	38,200	70,320	100,200
Total calcium	27,880	178,600	414,600
Total magnesium	18,500	58,320	136,800
Carbonate expressed as calcium carbonate (limestone)	9,282	3,094,001	911,820

portant soil types while a single sample was taken in case of some of the less extensive ones. The largest composite was made of samples of Barnes loam taken from 17 localities in the county. This type is quite generally distributed over the county and is associated with many of the other important types so that the amounts of the elements of plant food which it contains should furnish a general indication of the chemical composition of the soils of the county. The total amount of nitrogen, phosphorus, potassium, calcium and magnesium were determined according to approved methods ⁽¹⁾. The carbonates were determined by the cold dilute phosphoric acid method ⁽²⁾. The data is presented as pounds per acre. The total weight of the surface 7 inches of soil has been estimated at 2,000,000 pounds, the subsurface 4,000,000 and the subsoil 6,000,000.

In general the plant food content of the Barnes loam is fairly high. It compares very favorably with some of the productive soils of the corn belt, containing about the same amount of nitrogen, phosphorus, potassium and considerably more calcium and magnesium. The total amount of nitrogen now contained in the surface 7 inches is approximately equivalent to the amount contained in 120 thirty-bushel wheat crops. The total amount of phosphorus is equivalent to that contained in about 130 such crops and the amount of potassium equivalent to that contained in nearly 1,600 crops. The subsurface furnishes some elements of plant food to crops and as the surface wears away additional portions of it are becoming mixed with the plowed layer so that in considering the plant food content in terms of standard crops the figures should only be taken as an expression of the relative supply of the various plant food elements. From this standpoint it is evident that nitrogen and phosphorus should receive more attention than potassium in planning systems of soil management for the maintenance of the fertility of the Barnes loam. Calcium and magnesium are present in relatively larger amounts than potassium. The surface soil of an acre contains the equivalent of $4\frac{1}{4}$ tons of calcium carbonate (limestone), the subsurface about 150 tons and subsoil about 450 tons. This high lime content is an important factor in the adaptability of this soil to alfalfa production.

The total nitrogen, phosphorus and carbonate content of the more extensive types expressed as pounds per acre is presented in Tables IV, V, and VI.

In interpreting these figures it should be understood that the greater part of the feeding roots of crops are in the plowed layer or the top 7 inches of soil. While a great many roots grow into the subsurface and subsoil and no doubt secure some elements of plant food from these lower layers the best use of this store cannot be made unless the surface soil is kept in a high state of fertility. Farm manure and fertilizers are supplied to this layer and for ordinary

(1). The total nitrogen was determined by the Kjeldahl method and the total phosphorus by the magnesium nitrate method. Bulletin 107 (revised) Bureau of Chemistry, U. S. D. A. The total potassium by the J. Lawrence Smith method (modified); the total calcium and magnesium by fusion with alkali carbonates, Bulletin 261, Ohio Agricultural Experiment Station.

(2). Technical Bulletin No. 1, Tennessee Agricultural Experiment Station.

TABLE IV. THE AMOUNT OF THE IMPORTANT ELEMENTS OF PLANT FOOD CONTAINED IN BOTTINEAU COUNTY SOILS, SURFACE 7 INCHES.
POUNDS PER ACRE

	Total nitrogen	Total phosphorus	Limestone
	Pounds	Pounds	Pounds
Upland soils—glacial province			
Barnes silt loam	7,880	1,452	780
Barnes silt loam, stone free phase	7,060	1,272	750
Barnes clay loam	8,960	1,768	1,942
Barnes loam, clay subsoil phase	8,280	1,068	1,382
Barnes very fine sandy loam	6,920	1,106	4,630
Barnes very fine sandy loam, stone free phase	3,364	918	33,316
Barnes fine sandy loam	4,600	970	3,566
Barnes fine sandy loam, stone free phase	3,730	856	1,022
Williams sandy loam, rolling phase	1,826	818	2,502
Barnes loam, east of Mouse River	5,664	1,174	1,324
Barnes loam, Cut Bank Township	5,930	1,186	8,280
Barnes loam, Lansford Area	5,930	1,184	6,696
Bench land and lake bottom soils, —glacial lake and river terrace province			
Valentine fine sand	2,566	768	1,236
Fargo silty clay loam	9,560	1,726	2,210
Fargo clay, Scandia Township	7,180	1,412	52,234
Fargo clay, Oak Creek Township	10,080	1,174	52,916
Bottom land soils—river flood plains province			
LaMoure clay	7,520	1,490	164,710
Miscellaneous			
Peat	15,880 ⁽¹⁾	945 ⁽¹⁾	13,900 ⁽¹⁾

(1) An acre of peat soil to a depth of 7 inches is estimated as weighing 1,000,000 pounds.

conditions tillage is limited to this portion. The soil bacteria which make plant food available are more numerous and active in the surface soil. Consequently the plant food content of the surface 7 inches is of greater importance than that of the subsurface and subsoil and should receive more attention in planning systems of soil and management.

The nitrogen content of these soils is fairly high when compared with soils of older agricultural regions, and if legumes are grown and fed, and the manure returned to the land there is enough so that good yields of crops suited to the region can be produced. The sandy soils need to have legumes grown on them more frequently and more manure returned to keep up their nitrogen supply than will be necessary for the silt loams, clay loams and clays. The nitrogen and phosphorus content of the Valentine fine sand is quite low. This soil type needs to have these elements returned to it if it is to produce good crops. Most of the other soil types contain a fair supply of phosphorus for present crop needs. In the future it will be necessary to consider this element in planning for the maintenance of soil fertility. The fact that the surface of all soils analyzed contained some carbonate material and the subsurface and subsoil such a large amount would indicate that the practice of liming would be unnecessary for

TABLE V. THE AMOUNT OF THE IMPORTANT ELEMENTS OF PLANT FOOD CONTAINED IN BOTTINEAU SOILS, SURFACE 7-18 INCHES.
POUNDS PER ACRE

	Total nitrogen	Total phosphorus	Limestone
	Pounds	Pounds	Pounds
Upland soils—glacial province			
Barnes silt loam	7,320	1,704	4,112
Barnes silt loam, stone free phase	8,280	2,436	190,092
Barnes clay loam	7,400	2,136	14,012
Barnes loam, clay subsoil phase	4,588	1,508	1,680
Barnes very fine sandy loam	7,880	2,168	24,608
Barnes very fine sandy loam, stone free phase	4,152	1,596	92,820
Barnes fine sandy loam	4,120	1,628	199,836
Barnes fine sandy loam, stone free phase ..	5,176	1,624	8,268
Williams sandy loam, rolling phase	1,560	1,600	5,812
Barnes loam, east of Mouse River	6,520	2,044	148,328
Barnes loam, Cut Bank Township	5,960	2,252	305,960
Barnes loam, Lansford Area	5,048	2,040	5,960
Terrace and lake bottom soils —glacial lake and river terrace province			
Valentine fine sand	2,824	1,348	11,964
Fargo silty clay loam	1,600	2,668	162,432
Fargo clay, Scandia Township	10,080	2,656	222,848
Fargo clay, Oak Creek Township	8,920	2,324	292,108
Bottom land soils—river flood plains province			
Lamoure clay	11,520	2,616	430,428
Miscellaneous			
Peat	19,340 ⁽¹⁾	1,293 ⁽¹⁾	119,436 ⁽¹⁾

(1) The weight of the subsurface of peat is estimated at 2,000,000 pounds per acre.

alfalfa production in this locality. The presence of so much lime in the heavier soils helps to give them a more friable structure and makes it easier to produce a good mellow seed bed.

The Maple clay loam is characteristically an "alkali" soil and in order to ascertain the amounts of the more common salts in the type determinations of the bicarbonate, sulphate and chlorides have been made.¹

There is considerable variation in the soluble salt content of the two localities. In Sec. 33, Tp. 163, N. R. 77 W. the sulphates are the predominating soluble salts, while the soil from Sec. 10, Tp. 162, N. R. 77 W contains a higher percentage of bicarbonate. The salt content of an alkali soil varies with the distribution of the soil moisture so that the actual amounts of the various salts present is a temporary condition. The data furnishes an indication however, of the relative amounts of the various salts. There is considerable variation in the salt content of the type. This is in accordance with field observations. In some spots there is so much soluble material that there is practically no vegetation, while in others there is a rather

(1) The soluble alkali salts have been dissolved by extracting 25 grams of soil with 500 cubic centimeters of distilled water for 24 hours. The bicarbonates were determined by standard volumetric and the sulphates and chlorides by standard gravimetric methods.

heavy growth of grass. The high salt content of this type is largely due to its defective drainage. If it could be drained to remove the salts and manured to improve its physical structure its productivity would be much increased.

TABLE VI. THE AMOUNT OF THE IMPORTANT ELEMENTS OF PLANT FOOD CONTAINED IN BOTTINEAU SOILS, SUBSOILS 18-40 INCHES.
POUNDS PER ACRE

	Total nitrogen	Total phosphorus	Limestone
	Pounds	Pounds	Pounds
Upland soils—glacial province			
Barnes silt loam	51,840	3,042	742,580
Barnes silt loam, stone free phase	6,438	3,372	697,770
Barnes clay loam	10,560	3,630	329,862
Barnes loam, clay subsoil phase	5,310	3,030	487,302
Barnes very fine sandy loam	4,777	3,174	984,162
Barnes very fine sandy loam, stone free phase	3,108	2,508	408,132
Barnes fine sandy loam	3,665	2,244	498,222
Barnes fine sandy loam, stone free phase	3,768	2,622	578,030
Williams sandy loam, rolling phase	1,950	2,566	108,654
Barnes loam, east of Mouse River	4,872	3,090	2,035,212
Barnes loam, Cut Bank Township	4,248	3,060	814,902
Barnes loam, Lansford Area	2,832	3,036	1,864,042
Terrace and lake bottom soils—glacial lake and river terrace province			
Valentine fine sand	2,898	1,884	50,094
Fargo silty clay loam	6,132	3,204	1,270,190
Fargo clay, Scandia Township	7,230	3,552	606,060
Fargo clay, Oak Creek Township	5,948	3,228	556,920
Bottom land soils—river flood plains province			
Lamoure clay	8,700	4,542	728,910
Miscellaneous			
Peat	22,020	3,168	386,292

TABLE VII. THE SOLUBLE SALT CONTENT OF THE MAPLE CLAY LOAM, EXPRESSED AS SODIUM SALTS

No.	Depth— Inches	Type	Location	Sodium bicarbonate	Sodium sulphate	Sodium chloride
				Percent	Percent	Percent
1301	0-7	Maple clay loam	N. W. of N. E. Sec. 33.... Tp. 163 N. R. 77W.	0.1169	2.1519	Trace
1302	7-18	Maple clay loam	N. W. of N. E. Sec. 33.... Tp. 163 N. R. 77W.	0.1040	3.1185	.0210
1303	18-40	Maple clay loam	N. W. of N. E. Sec. 33.... Tp. 163 N. R. 77W.	0.0884	4.2418	.0031
1347	0-7	Maple clay loam	N. W. of N. W. Sec. 10.... Tp. 162 N. R. 77W.	0.7480	0.1067	.0245
1348	7-18	Maple clay loam	N. W. of N. W. Sec. 10.... Tp. 162 N. R. 77W.	0.4020	.0495	.0123
1349	18-36	Maple clay loam	N. W. of N. W. Sec. 10.... Tp. 162 N. R. 77W.	0.1440	0.0000	.0052

Taken as a whole the chemical analyses of Bottineau County soils compare favorably with those of rich agricultural regions. Like many of the other soils of the middle west they are lower in nitrogen and phosphorus than in the other important elements when measured on the basis of standard crop demands. They differ from the soils of the more humid regions in the middle west in that they contain much larger amounts of calcium and magnesium. They also contain larger amounts of limestone or calcium carbonate. Owing to defective drainage small areas contain considerable amounts of soluble salts. These areas constitute a very small percentage of the land in Bottineau County.

THE MANAGEMENT OF THE SOILS OF BOTTINEAU COUNTY

The great diversity of soil types in Bottineau County calls for considerable variation in the management that they should be given. In this locality economy of soil moisture is probably the most important object of all soil management. In general there are four ways in which the available moisture can be used most economically (1) by practicing such tillage methods as will enable the soil to absorb and retain as much of the rainfall within reach of crop roots as possible, (2) by growing crops that will make the most economic use of the moisture supplied to them, (3) by growing crops in such succession that advantage may be taken of the favorable soil moisture conditions created by the culture and growth of certain crops and (4) by the elimination of weeds which rob the growing crops of large amounts of soil moisture.

The topography of the county, with the exception of the Turtle Mountains is such that there is very little water lost in the runoff. In some of the sandy soil types, however, there is some loss of water through percolation into the lower soil layers. This can be prevented to some extent by keeping the soil as compact as possible and keeping it well supplied with organic matter. The rains have very little packing action on the soil in this region so that it takes the soil some time to settle after being plowed. The sandy soils which have a tendency to become loose, therefore, should be stirred as little as possible and at the same time control the weeds. This is accomplished by following a rotation which makes it unnecessary to plow every year. For example in a simple rotation like

corn 1 year,
wheat 1 year,
grass 1 year,

it is necessary to plow but once. The land would be plowed for the corn, the wheat seeded on the corn stubble land without plowing, the grass being seeded with the wheat. While this rotation would probably not be suited to many farms in the county under present conditions it illustrates a method of keeping the sandy soils in a compact condition. Some of the sandy soils drift badly, especially when plowed in the fall. This can be retarded to some extent by giving such lands a top dressing of manure in the fall and winter. Drifting can also be checked by covering the soil with straw. When this straw decays it adds to the supply of organic matter in the soil and is of permanent benefit.

Corn and alfalfa make about as good use of the available moisture as any crops suited to the region. The cultivation given the corn crop removes the competing weeds and keeps the soil in good condition to absorb and retain the soil moisture in the plowed layer where better use can be made of the available plant food. Alfalfa begins to use soil moisture early in the spring and by means of its long roots uses it from the soil to a considerable depth as fast as it is supplied by the rainfall. Winter rye makes use of the early spring moisture to better advantage than spring sown crops.

When spring wheat or other small grain follows corn, fairly good use is made of the soil moisture because the extra supply is used in producing a crop especially well suited to the climate of the region. In other words the favorable soil conditions left by the corn crop help to balance the climatic conditions for the growth of wheat. The uniformly compact structure of the seed bed makes possible a more complete distribution of soil moisture to the crop roots.

The elimination of weeds is essential if the best use is to be made of soil moisture. Where a wheat field consists of half wild oats, only half of the available moisture can be used in the production of wheat. In case the available soil moisture is sufficient for 30 bushels of wheat the wild oats would reduce the yield to 15 bushels. While fields containing such a large percentage of wild oats are unusual many contain enough to reduce the yield materially. The growing of inter-tilled crops like corn and potatoes and the growing of alfalfa are the best means of controlling the weeds which are most common in the region. The growing of winter rye helps to keep certain weeds in check. Bare fallow if well tilled stores some moisture and is a good preparation for small grain but no return is secured from such land the year it is fallowed while corn or potatoes will furnish an income with very little additional cost.

The tilth of most of the soils of Bottineau County is very good but certain extreme conditions demand special treatment. One of the serious problems is to prevent the drifting of the coarser textured loose soils. The best way to improve these soils permanently is to increase their content of organic matter. After organic matter has reached a certain stage of decay it holds the coarser soil particles together and thereby has a tendency to retard drifting. Grass roots left in the soil after hay crops have been grown have a binding effect on loose soils. If large amounts of organic manures are plowed under on light soils for small grain the soil is apt to dry out rapidly. It is usually a better practice to apply the fresh manure as a top dressing on plowed land and disk it in, plow it under for corn or spread it on pasture land that is in the regular cropping system. Temporary measures may be adopted that will help to control drifting soils such as covering the land with a coat of manure or straw. It is not advisable to apply more than 1½ tons of straw to an acre. Drifting can be avoided to a great extent by planning the rotation so that it will not be necessary to leave the soil bare during the winter. The seeding of winter rye in the stubble and the practice of spring

plowing keeps the soil in condition during the winter so that it will not be so likely to drift.

In a rotation of

corn 1 year,
barley 1 year,
winter rye 1 year,
wheat 1 year,
sweet clover 1 year,

—the ground for the corn

could be plowed in the spring, no plowing would be necessary for the barley, the winter rye could be stubbled in and the land plowed in the spring for wheat. If the corn ground is inclined to drift manure can be spread on it in the fall after the crop is removed. If one wishes to take advantage of the early plowing made possible by the early ripening of the winter rye the ground could be plowed in midsummer and covered with manure or straw during the winter. In some cases the soil drifts badly on newly seeded alfalfa. This can be prevented by giving it a light covering of manure. After the alfalfa is well started it will control drifting soils very well.

Some of the finer textured "gumbo" soils are very hard to till and if not handled right it is difficult to work them into a good seed bed. The Fargo clay and Fargo silty clay loam belong to this class of soils. If plowed when too wet they sometimes bake and when an attempt is made to prepare a seed bed shortly after plowing the land works up cloddy. If plowed when too dry large lumps or clods are turned up and it is difficult to prepare a good seed bed. If these soils are plowed in the fall when the moisture content is as near right as possible they mellow down during the winter and an excellent seed bed can be produced in the spring. The tilth of these fine textured soils is injured by driving over the land when it is wet. When these clay soils are in good tilth the small soil particles are united into groups or granules and the soil is said to have a "crumb" structure. When this is fully developed they are mellow and in fine condition for the seeding and growth of crops. When fine textured soils are handled when wet the granules are broken up and the small particles run together and form large clods that are more or less impervious to water and air. The growing of legume and grass crops in the rotation promotes a granular condition in these fine textured soils. The growing roots produce lines of cleavage between soil particles and when they decay open spaces are left between the soil granules. The application of farm manure has a similar effect upon clay and clay loam soils. Where small grains are grown exclusively there is a tendency for clay soils to become soggy and "dead." The application of manure or the growing of hay crops in the rotation makes such soils mellow and friable. Drainage improves the structure of these soils materially.

While the county is in a comparatively new agricultural region and small grain has been the principal source of income on all farms, in the future many of the farms of the county would be more profitable if forage crops had a more prominent place in the cropping system than at present. In the past the cropping has been much the same on all soil types. It is obvious, however, that the same cropping will not be equally well adapted to the Fargo clay and the Valentine

fine sand. The finer textured soils, the clays, clay loams, silty clay loams and silt loams are the strongest soils in the county and they will be able to support a cropping system containing a larger acreage of grain crops than the sandy loams. On the other hand the sandy loams are warmer soils and corn will grow faster and be more likely to mature. For this reason corn should have a larger acreage in the cropping system than on the heavier soils. Some of the coarser textured Sioux soils have water fairly close to the surface and no doubt some of these could be used more profitably in the production of alfalfa than in any other way.

The demonstration farms which are under the supervision of the Experiment Station have been established to show what can be accomplished by growing crops in a rotation, the return of farm manure, and the use of good seed in various localities in the state. The farms consist of from four to seven fields depending upon the length of the rotation. There are as many fields as there are years in the rotation, and all crops in the rotation are grown every year, one on each field. The crops follow each other on the various fields in regular order as the years advance. Manure is applied at the rate of 10 to 12 tons per acre for the corn. The yield of each crop is kept and the tillage and management of the crop are recorded. The records of these farms furnish information concerning the crop adaption of the soil on which they are located and are of service in ascertaining what can be accomplished by a fair system of soil management. Three of these farms are located in counties immediately adjacent to Bottineau and furnish evidence concerning the use of certain soils in this county.

The farm located west of Mohall is only a short distance from the county line. The results on this farm apply more directly to the soils in the western part of the county, especially the Barnes loam and Barnes silt loam. The results at Granville apply more especially to the coarse textured soils in the south central part of the county and those on the Rugby farm more especially to the Barnes very fine sandy loam. These farms are all located fairly close to the county and the results apply to quite a large part of the county. Not all of the crops that are adapted to the soils of the county have been grown on these farms but crops commonly grown in the region have been grown and the yields recorded thereby furnishing definite information for these crops.

The Granville demonstration farm is located on sandy soil similar to some of the coarser textured types of Bottineau County. During the nine year period, 1906 to 1914 corn was planted on one field each year. In 1910 an extremely dry year, the corn as well as all other crops was a failure. Corn was planted on one of the plots that is somewhat more sandy than the rest of the farm in that year. Corn matured 5 years of the remaining 8. The yield of shelled corn was determined for 3 years of these 5 and the average yield was 33.75 bushels per acre. Calculating the yield to a fodder basis for the 8 years that crops were harvested the average yield was 1.45 tons per acre. In 1911 corn was the only crop that was not a failure.

Durum wheat has been seeded five times. The crop was a failure in 1910 and the average yield for the other 4 years was 13.34 bushels

per acre. Blue stem wheat was seeded 4 years. It failed in 1911 and the average yield for the remaining 3 years was 16.28 bushels. The average yield for the 9 years wheat was seeded including the years in which it failed was 11.34 bushels per acre. Oats and peas were seeded six times and failed in 1910 and 1911. The average yield of hay for the 4 remaining years was 1.72 tons per acre. Barley has been seeded five times. It failed in 1910 and the average yield for the remaining 4 years was 17.16 bushels per acre. Flax was a failure 1 year out of 4. The average yield for the 3 remaining years was 7.78 bushels per acre. Winter rye averaged 12.5 bushels per acre for the 3 years it was grown and three crops of oats averaged 44.41 bushels per acre.

Corn has been the most consistent crop for the entire period while oats and oats and peas for hay have made fairly good showing. The exceptionally good average yield of oats was partly due to the fact that they were grown in two favorable years but when compared with other small grains grown the same year they have an advantage. Winter rye might prove profitable in favorable years if the cost of production is not too high.

The Mohall demonstration farm was established in 1910. This farm is located for the most part on Barnes loam and Barnes silt loam. Corn matured 3 years of the 5 during the period of 1910 to 1914. The average yield of shelled corn for these years was 34.8 bushels to the acre. The average yield of fodder for the other 2 years was 2.29 tons per acre. The average yield of the blue stem and durum wheats grown during this period have been 13.5 bushels to the acre and 20.17 bushels to the acre respectively when both were grown in the same year. Durum was grown in 1910 an unfavorable year so that its average yield for the 5 years is 15.43 bushels. Durum wheat being seeded on corn ground, has a more favorable place in the rotation than blue stem, which no doubt accounts largely for its better yield. Oats and peas grown 3 years produced an average yield of 1.37 tons of hay per acre. Timothy and clover yielded a little over a ton to the acre in 1913 and German millet about the same in 1914.

The rotation of this farm during the 5 year period 1910-1914 was

corn, 1 year,
durum wheat, 1 year,
oats 1 year,
blue stem wheat, 1 year, and
oats, and peas 1 year,

"During this period a net profit of \$3.26 per acre has been obtained from this farm or a net profit of \$1.043 on a half section farm with such a rotation after all expenses have been paid that are involved in producing farm crops." (1)

The Rugby demonstration farm is located for the most part on Barnes very fine sandy loam, stone free phase, and Barnes silt loam and is representative of quite a large area in Bottineau County. This farm was established in 1909. The rotation followed for the most part has been:

(1) Ninth Annual Report North Dakota State Demonstration Farms, p. 30

corn 1 year,
wheat 1 year,
barley 1 year,
oats and peas 1 year, and
wheat 1 year.

Mature corn has been produced 3 years of the 6 that the farm has been operated. The yield of grain was not determined in 1909, the fodder yield being 1.59 tons per acre. The average yield of the fodder for the 3 years the corn did not mature was 1833 pounds per acre. This included the extremely dry year of 1910 when all other crops except wheat on corn ground were an entire failure.

The average yield of wheat during the 6 year period has been 16.14 bushels per acre. Barley has averaged 27.07 bushels per acre and oats and peas 1.65 tons of hay per acre.

The Langdon substation in Cavalier County is located on a soil similar to the Barnes very fine sandy loam so that the results at this station will apply in a large measure to this type. Where barnyard manure has been applied in the fall preceding the year in which corn is grown in a 6 year rotation there has been an average increase of 1.23 tons per acre of fodder as an average of 3 years. Two years results with oats following this corn has shown an average annual increase of 5.09 bushels per acre due to the manuring of the corn. The manure has shown an increase of 3.89 bushels per acre for the wheat crop following the oats in such a rotation.

If the productive capacity of the soils of the county is to be maintained at its highest point crops must be grown which are adapted to the respective soil types. These crops must be grown in a rotation that will provide for the control of weeds, the maintenance of good tilth, an adequate supply of decaying organic matter in the soil and the economic use of soil moisture and plant food. In a well balanced system of farming the necessary livestock will convert the forage crops and straw into manure. This should be returned to the soil with as little loss as possible. When applied to the right crops in the rotation it will produce a material increase in yield.

The foregoing results secured on the demonstration farms in this locality and on the Substation at Langdon show that when attention is given to crop rotation and the use of farm manure fair yields will be obtained. When more forage is grown in the rotation, fed on the farm and all of the straw returned to the land in the manure, more profitable yields will be obtained on the lands that are now cropped to small grain exclusively.

SUMMARY.

The soils of Bottineau County have been derived from glacial drift. A considerable portion of the drift still remains in the same position as when deposited by the ice sheet having been modified only by weathering and vegetation. The drift in the remainder of the county has been reworked to some extent by water and wind.

The topography of the county with the exception of the Turtle Mountain region is level to undulating. The Turtle Mountains are rolling and contain many small depressions some of which are ponds and lakes.

The drainage system is not extensive and some areas could be improved by artificial drainage. As a whole the drainage of the county is adequate to take care of the rainfall except in limited areas.

The soils of the county may be placed in three general groups: Upland, Bench land and Lake bottom, and Bottom land soils. The Upland soils are divided into the Barnes, Williams and Valentine series, the Bench land and lake bottom soils into the Fargo, Rogers and Maple series, and the bottom land soils are in the LaMoure series.

The soils of the Barnes series cover the greater part of the county. The Barnes very fine sandy occupies a large part of the county and is suited to general farming. It is inclined to drift in some localities but this can be controlled by a system of cropping that will keep the soil in a compact condition during the winter and spring. The Barnes loam is also a very extensive type suited to general farming. It will stand heavier cropping to small grain than the very fine sandy loam. The heavy subsoil phase of this type in the Turtle Mountains is more rolling than the typical phase but has a higher water holding capacity. The Barnes silt loam is one of the best soils for general farming in the county. The Barnes clay loam and clay in the mountains are productive soils and a large proportion of their area will eventually be brought under cultivation. The Barnes fine sandy loam has a lower water holding capacity than the finer textured types of this series but if properly managed good crops can be produced. Corn, potatoes and alfalfa should occupy a prominent place in the cropping system on this type.

The soils of the Williams series in this county are quite rough in topography and are low in water holding capacity. A considerable area of these types is better suited to grazing than to the growing of crops.

The Valentine fine sand is inclined to drift and special care should be taken to keep the soil as compact as possible. This can be accomplished by planning the cropping system so that the land will not need to be plowed every year. Corn, sweet clover, and alfalfa should have an important place in the rotation on this type. Oats, winter rye and durum wheat can be used to advantage as grain crops. The use of farm manure will increase the productive capacity of this soil materially. Light applications in the fall will keep the soil from drifting in the winter and spring.

The soils of the Sioux series have a gravel subsoil and a low water holding capacity. They occupy a lower topographic position and receive some drainage from the Barnes soils, however, and in some areas will withstand drouth fairly well. The water table is fairly close to the surface in some areas. Corn, potatoes, alfalfa and sweet clover should have a place in the rotation on these types and oats, winter rye and durum wheat can be grown successfully on the better types.

The Fargo clay is one of the most fertile soils of the county but is not as well drained as some of the others. It is a good small grain soil but corn and potatoes can be grown to advantage in the rotation. Alfalfa and grass should also have a place in the cropping system. This soil should be fall plowed as it is frequently difficult to work it into

a mellow seed bed when plowed in the spring. The Fargo silty clay loam has many of the characteristics of the Fargo clay but is more easily tilled and better suited to the growth of corn and potatoes.

The Maple clay loam and the Rogers clay loam contain alkali in sufficient quantities to be injurious to crops. They are poorly drained and hard to cultivate. They probably can be used to the best advantage as pasture and wild hay land. Some areas could be improved by drainage and applications of farm manure.

The LaMoure clay in the Mouse River bottoms has not been cultivated to any extent but with proper management it can be used in the production of the common crops of the regions. Alfalfa should do well on this type. On account of its high content of clay it is difficult to cultivate and fall plowing should be practiced. The application of farm manure and the growing of alfalfa will help to loosen the structure.

The chemical composition of the soils of the county compares favorably with those of rich agricultural regions. Like other soils of the middle west the nitrogen and phosphorus content is relatively low when measured on the basis of standard crop demands. The magnesium, calcium and carbonate content is higher than in the soils of the more humid states of the corn belt.

Small areas contain "alkali" or soluble salts in sufficient quantities to injure crops but those areas constitute a very small percentage of the county.

The economic use of soil moisture is one of the greatest problems of the county. This can be accomplished by practicing a well balanced system of cropping which will eliminate weeds and provide for a succession of crops that prevent excessive loss of water from the surface of the soil. Better tillage methods will be of some help but unless accompanied by a rotation of crops the best results can not be obtained.

The supply of organic matter in many of the soils has been materially reduced and a new supply is needed to promote the conversion of inert plant food into available form. This can be most economically supplied by the return of farm manure.

Results obtained on the Rugby, Mohall and Granville Demonstration farms and the Langdon substation show that good yields can be obtained on the representative soils of the county when a rotation of crops is followed, good seed used and farm manure returned.



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99
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North Dakota Agricultural Experiment Station

Notes on Parasitic Anaphylaxis and Allergy
By L. Van Es and A. F. Schalk

Bulletin No. 125

Agricultural College, North Dakota
October 1917

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* Detailed to North Dakota Experiment Station by the United States Department of Agriculture.

NOTES ON PARASITIC ANAPHYLAXIS AND ALLERGY

By L. Van Es and A. F. Schalk

Ever since the time when Vallée and Carré (1, 2, 3)* published the results of their investigation of infectious anemia of the horse, European as well as American experimenters have been unanimous in regarding this disease as due to a specific ultramicroscopic virus.

The infectious nature of the disease has not been questioned, not only because of its capability of being readily communicated to other horses, but above all from the standpoint of its epidemiology. Its apparent localization in certain regions, on given farms even, was so characteristic that doubt was no longer reasonable.

It is not surprising, thus, that a new explanation of the etiology of this disease received considerable attention from those engaged in its investigation.

Such an explanation was attempted by K. R. and R. Seyderhelm of Straszburg, who in three publications (4, 5, 6) appearing during 1914, made known the results of their studies and their conclusions.

In the first of those three publications (4) the author relates his findings in a study undertaken in order to throw light on the nature of the primary anemias of man. The author deemed it useful, in order to better understand the nature of anemia in general, to make an investigation of similar diseases occurring among animals. Among those the horse disease known as infectious or pernicious anemia seemed to offer a promising field of research.

Considerable of the author's effort was devoted to the pathologic anatomy and the findings already published by this station some years before (7) were either confirmed or elaborated.

The author's study of the blood changes revealed a constant increase in its color index, in spite of an abnormally low absolute hemoglobin content.

Leucopenia was frequently found as well as lymphocytosis, and a reduction of the eosinophiles down to their complete absence. The blood platelets were constantly reduced and toward the fatal termination were entirely absent.

Seyderhelm is struck by the contrast between the blood findings and the changes found in the organs. In the blood there is no indication of an increased blood formation. On the other hand, one is surprised to find a very red bone-marrow and highly marked myeloid changes in the secondary blood forming organs. Liver and spleen are stuffed with enormous cell masses, all stages of erythropoiesis and leucopoiesis being ranged alongside each other. In spite of this well developed reproduction of the initial stages of all blood cells, nothing of this is, according to the author, to be found in the blood.

In comparison with the numerous lymphocytes, the myelocytes and finished leucocytes are less conspicuous. Alongside of this there are all the phases of erythropoiesis.

*Numbers refer to references on page 192.

The author found in all his cases a more or less extensive myeloid change of the spleen.

Myeloid cell accumulations in the liver are divided over two groups. One, extravascular, periportal, consisting of myelocytes and leucocytes and an intracapillary one, composed of lymphocytes and normoblasts.

While in the publication just mentioned Seyderhelm appears to be in accord with the prevailing views relative to the etiology of the disease, the authors of the second publication (5) came to an entirely different conclusion.

Certain indications met with in literature, as well as in information obtained from owners, made it appear probable to the authors that there exists an intermediary host or carrier. The seasonal incidence of the disease strengthened them in this belief, and because of the fact that of all the insects and parasites found, the larvae of *Gastrophilus* were the only ones constantly present in all of the 85 cases examined, they suspected that those parasites had a certain relation to the disease.

The question which presented itself to the Seyderhelms was: Can the disease be transmitted to a healthy horse by means of the intravenous injection of the extract of *Gastrophilus* larvae, taken from horses affected with infectious anemia?

On November 30, 1911, they cleaned by means of repeated washings, four larvae of *Gastrophilus equi*, which were taken from a horse dead with infectious anemia. While gradually adding 50 c. c. of a physiologic salt solution, the larvae were crushed, the mixture immediately filtered and used for the injection.

The intravenous injection was made slowly. The authors report the following observations: After 3 minutes, the pulse became more rapid and after 2 minutes more the animal became markedly uneasy, defecated repeatedly, stretched its neck forward and commenced to tremble. The rate of respiration increased to 32 p. m. There was profuse sweating over the entire body, the animal showed a marked inclination to vomit, the nostrils were dilated, while the saliva and nasal mucus flowed profusely. The conjunctivae were injected and very red in color, there was lachrymation, dyspnea made its appearance, the pulse rate increased to 120 p. m. and 8 minutes after the injection could no longer be felt. Six minutes after the completion of the injection, the animal commenced to stagger in a conspicuous manner. There was an increasing weakness, especially of the hind extremities and 3 minutes after the injection the animal fell to the ground, drew its neck backward and expired 12 minutes after it received the extract.

The autopsy revealed the peripheral vessels markedly dilated and where they were severed, they emitted a dark-red non-coagulated blood. All mucosae were dark red, injected, permeated by quite extensive hemorrhages. Above all the mucosae of the stomach, colon, cecum and rectum presented the picture of the severest type of acute hemorrhagic gastro-enteritis. All organs appeared hemorrhagic, everywhere escaped non-coagulated tar colored blood upon cross section. The spleen above all was softened and when cut into,

it presented the appearance of a black mush. The liver also was markedly hyperemic, while the kidneys showed numerous hemorrhages especially in the cortex. The heart, on its surface, looked as if spattered with blood, was covered by numerous quarter-sized hemorrhages and a similar picture was shown by the endocardium. The lungs also were engorged with blood.

Before the authors risked to draw further conclusions from their observations, they injected an extract, made in a similar manner from four other larvae, taken from the same horse, intravenously into a rabbit. This animal showed no reaction whatever. Similar trials were made with dogs, mice, chickens, pigeons, hogs, sheep and cattle. It was found, that the only animal aside from the horse, reacting, although more feebly, is the ass.

To the Seyderhelms, it appeared probable, that the *Gastrophilus* larvae contain a substance specifically toxic for the horse. To this substance they gave the name "oestrin".

The investigators asked now: Is this finding merely coincidental or has it in some way a relation to infectious anemia? In their experiments, designed to find an answer to this question, they used 20 healthy horses, of which 8 became the victims of the eminently toxic action of the "oestrin". They injected hundreds of larvae, procured from various sections of Germany and nearly always observed the same characteristic reaction as described. They furthermore observed, that larvae taken from healthy horses did not differ in their action from those removed from horses affected with infectious anemia. They further found that the larvae of *Gastrophilus hemorrhoidalis* were especially toxic.

In the cases which survived the injections, increases in the body temperature were observed, while a more or less marked loss of weight was one of the sequelae noted. The temperature curves observed by the Seyderhelms, conveyed the impression that they were dealing with an infection by some pathogenic organism. By this consideration, they were induced to inquire, if they were confronted by some bacterium or ultra-microscopic organism, or a definite chemical substance of a poisonous character, contained in the larvae and which brought about this typical reaction in the horse?

In the course of their experiments designed to throw light on this point, they found that a continued heating for several hours in the autoclave failed to deprive the extract of its toxic principles.

They further studied the effects of chemicals upon the *Gastrophilus* extracts. In this they observed that a day's exposure to 96% alcohol could not influence its action, while the same can be said of such agents as ether, chloroform, acetone, iodine-trichloride and chloride of calcium.

It was also found that the substances spontaneously eliminated from living *Gastrophilus* larvae also were toxic for the horse.

In their experiments, three healthy horses were repeatedly injected with the *Gastrophilus* extracts, and as a result of those trials the authors concluded that it is possible by the use of correctly graded doses to bring about a febrile anemia, progressively leading to death, and which, clinically, patho-anatomically, histologically

and hematologically can in no way be distinguished from the pernicious anemia of horses. The authors also obtained a very marked reaction with an extract prepared from the egg-bearing *Gastrophilus* fly after its intravenous injection into one of the three horses mentioned. The next step in the Seyderhelm experiments was an attempt to transmit disease with the blood from horses made sick with larval extract only. This was successful in the two cases tried, while it was further found to be possible to transmit disease from animals so treated to a third horse.

The results obtained are stated by the authors as follows: "By the injection of a substance contained in *Gastrophilus* larvae and in flies, specifically toxic for the horse and to which we have given the name of "Oestrin", it is possible to cause a severe anemia in horses, which, with a febrile course, clinically resembling an infectious disease, causes death. This artificially produced disease can be conveyed to healthy horses by means of the blood, but not to other animals. The character of the disease remains the same thereby. Also, the disease caused by transmission causes death. Owing to the fact, that the disease in horses caused by *Gastrophilus* extracts, behaves itself in all details, clinical, hematological, patho-anatomic and especially histologic, exactly like pernicious anemia of horses. Owing to the fact that also this artificially produced disease can be conveyed to healthy horses by means of the blood and from those again to others, and owing to the further fact, that in all cases of pernicious anemia of horses, there are attached to the stomach wall *Gastrophilus* larvae, the following conclusion is imperative":

"The pernicious anemia of horses is not caused by an ultravisible microorganism, but by a toxic substance, oestrin, especially secreted by *Gastrophilus hemorrhoidalis* and exclusively specific for the horse. As, this disease brought about by a chemical substance and clinically making the impression of an infectious disease is transmissible to healthy horses, there is a reason for proposing a new explanation for this type of transmissibility".

The Seyderhelms further take pains to enumerate the reasons, why they think, that microorganisms play no part in the results which they recorded. Among those reasons, it is interesting to note the following statement: "If pathogenic microorganisms in the *Gastrophilus* larvae were the cause of pernicious anemia, the mechanism of action would be different. In connection with a single injection, pernicious anemia would develop after the expiration of an incubation period. The extracts, however, act always in direct consequence of the injection in the sense of a poison action and only after frequent administrations, there develops gradually the clinical picture, which must be identified as pernicious anemia."

The question why do only a part of the horses harboring *Gastrophili* contract pernicious anemia is met by the statement, that this problem is a general one. It does not exclusively pertain to the *Gastrophilus* larvae, but is seen in human pathology in the case of *Bothriocephalus* and other parasites, above all in that of pathogenic microorganisms. Why are the latter found in perfectly healthy

persons? The individual disposition as parasite host, no doubt plays a part.

In further support of the authors' contention relative to the part played by *Gastrophilus*, they point out the synchronous occurrence of infectious anemia with the bot fly season, and the association of the disease with pasturing. The apparent lack of evidence of transmission by contact, as well as the part played by *Gastrophilus hemorrhoidalis* is also pointed out in the article under consideration.

In regard to the *Gastrophilus hemorrhoidalis* the Seyderhelms state that those specially toxic larvae pupate in the stable soil or floor and that the resulting flies deposit their eggs in the same place. They also say, that in stables kept hygienically and in those where thorough grooming is a feature, the disease does not occur.

In their epicritical considerations, the authors say this in regard to the agent which in the transmission of disease from the bot injected horse to a healthy one is responsible for this fact: "What the nature of this agent is can at this time not be said with certainty. However, this agent shows in the behavior of the blood toward physical and chemical influences different characteristics as those of "oestrin". Above all is it thermolabile? It is possible that there is concerned an ultraviolet disease producer, which is encapsulated in the organism of the horse, or which occurs in a dormant stage and which by the oestrin is set free and rendered capable of reproduction. Or, it may be an agent of chemical construction, which oestrin sets free from certain tissue constituents of the horse and which is capable of acting upon healthy tissues exactly like oestrin, that is to set free its equal from the tissue constituents.

In their third publication (6) the Seyderhelms discuss pernicious anemia of man and its possible analogy with that of horse. They also briefly review the knowledge relating to the latter as gathered from existing literature. Patho-anatomic and hematologic investigations are also discussed, while their findings relative to the action of *Gastrophilus* extracts as published in the article reviewed above are also summarized, followed by a critical discussion of their possibilities in the light of our present day knowledge of the anemias.

In this third publication, therapeutic experiments dealing particularly with trials to cure the disease by eliminating the bots from the stomach are related. The authors did not expect success with this form of treatment, because the anemic horses probably had absorbed the fatal dose of oestrin. Theoretically, there may be cases of a light degree in which the elimination of the larvae may have the desired results. The Seyderhelms state that of six horses affected with pernicious anemia there were two, which were in the initial stages of the disease and which were cured by removing the bots. The remaining four died in spite of the treatment.

In regard to an attempt to prepare an immune serum the authors say that experiments to immunize horses against oestrin were futile for a long time, but that they finally succeeded to do so under certain modifications. They promised to describe the preparation of the serum at a later date. They treated 16 horses affected with pernicious anemia with this serum. They first eliminated the bots and

then injected their serum, sometimes repeating the injection. The authors state that of the 16 horses so treated, nine made a full recovery.

Experiments were also made along the line of prophylaxis. Two horses received infectious serum only, and two others received in addition to the infectious serum also a dose of antiserum.

In the first trial, only the horse which had not received the antiserum became sick. In the second trial the difference was also marked. The animal which had also received the antiserum showed transitory rises of temperature but no reduction of hemoglobin. Further experiments of this nature were held in prospect.

The experimental results reported by the Seyderhelms cannot have failed to arouse an interest, in any student or observer of the disease of the horse, known as infectious anemia or swamp-fever in this country, even if accompanied by some degree of doubt. Not because the conception of an insect carrier playing a part in transmission was either new or unexpected, but on account of their rejection of a living pathogenic microorganism as a causative factor in what has for several years been recognized as a communicable disease.

To say the least the results reported would not very well be accepted at their face value without challenge, and accordingly the writers undertook certain experiments in order to obtain additional light on the new theory advanced by the two Alsatian investigators. Owing to the fact, that a scarcity of field material had interrupted their regular investigations of swamp-fever, they were enabled to devote considerable more time and material to those experiments than otherwise would have been the case.

In the first place our efforts were directed toward a study of the possible results following the injection of *Gastrophilus* material into healthy horses.

The following notes extracted from our records indicate the results obtained.

EXPERIMENT WITH HORSE NO. 2612

This was a healthy old horse purchased for experimental purposes. Before injection the pulse rate was 36 p. m., respiration 18 p. m. and the temperature 99° F. Bowel evacuations and general sensibility were normal.

Ten *Gastrophilus* larvae of unidentified species were taken from the stomach of horse No. 2548, a swamp-fever field case. The ten larvae were crushed with physiologic salt solution and filtered through loose cotton. After washing the filter, the suspension or solution of bot material amounted to 12 c. c. and this was injected intravenously into horse No. 2612. The injection was made at 9:42 A. M. on November 21, 1914.

9:45 A. M. Pulse 75 p. m. Respiration 45 p. m. Temperature 99.8° F. Peristalsis and evacuations were normal. There was a beginning of diaphoresis. Increase in sensibility. Increase of blood pressure.

9:50 A. M. Pulse 90 p. m. Respirations 52 p. m. Temperature 100.1° F. Peristalsis became violent. Evacuations were softer. There was profuse sweating and the animal was excited.

- 9:55 A. M. Pulse 90 p. m. Respirations 45 p. m. Temperature 100.1° F. Peristalsis was less violent. The bowel discharges were liquid. The sweating was profuse, but the animal was more quiet and the blood pressure was lower.
- 10:00 A. M. Pulse 72 p. m. Respirations 38 p. m. Temperature 99.8° F. Peristalsis was becoming less violent. Liquid evacuations. The sweating decreased. Sensibility sub-normal. The blood pressure was about normal.
- 10:05 A. M. Pulse 70 p. m. Respirations 36 p. m. Temperature 99.8° F. Liquid evacuations. The sweating decreased. The sensibility was sub-normal. The blood pressure was sub-normal.
- 10:10 A. M. Pulse 70 p. m. Respirations 30 p. m. Temperature 98.6° F. No peristalsis. No evacuations. No sweating. Sensibility and blood pressure sub-normal.
- 10:15 A. M. Pulse 66 p. m. Respirations 23 p. m. Temperature 98.4° F. No peristalsis. Some liquid evacuations. There was no sweating and the sensibility and blood pressure were sub-normal.
- 10:30 A. M. Pulse 72 p. m. Respirations 16 p. m. Temperature 100° F. Watery evacuations. Sensibility was sub-normal. The blood pressure again normal.
- 11:00 A. M. Pulse 79 p. m. Respirations 13 p. m. Temperature 100° F. Peristalsis was slightly audible. Semi-solid evacuations. No sweating. The sensibility sub-normal.
- 12:00 M. Pulse 54 p. m. Respirations 13 p. m. Temperature 100° F. Semi-solid evacuations. Sensibility returning.
- 1:30 P. M. Pulse 40 p. m. Respirations 13 p. m. Temperature 100° F. There were no bowel evacuations. No sweating. Animal much brighter. The blood pressure was normal.

The evening temperature of the day of injection was found to be 103.2° F. and during the 134 days which the animal was permitted to live, there were several times when the body temperature rose a little, but it only once came up to 102° F.

The autopsy revealed a considerable degree of interstitial hepatitis, while the heart showed a few sub-endocardial ecchymoses. The gross appearance of the other organs was normal. Neither anemia, nor albuminuria were observed in this case.

EXPERIMENTAL HORSE NO. 3294

This animal was purchased as a suspected case of swamp-fever, but the diagnosis remained very doubtful. Nine larvae of *Gastrophilus* (No. 3401) of which the species was not definitely determined and which were collected in the vicinity of Chicago, were crushed in a mortar and macerated for 48 hours in a physiologic salt solution at refrigerator temperature. At the end of this period, the mass was shaken, filtered, the filter washed with more of the salt solution and the filtration repeated.

On September 27, 1915, the filtrate was injected intravenously into horse No. 3294, the injection being completed at 3:55 P. M. Before the injection the pulse was 48 p. m., respirations 11 p. m., temperature 100° F.

The following observations were made after the injection.

- 3:58 P. M. Defecation.
- 4:00 P. M. Respirations 40 p. m. Defecation. Sweating. Salivation. Mucous discharge from nostrils.
- 4:02 P. M. Pulse 80 p. m.
- 4:05 P. M. Respirations 30 p. m., defecation.
- 4:10 P. M. Pulse 73 p. m. Temperature 99.6° F. Long strings of mucus dripping from nostrils. Profuse sweating.

- 4:15 P. M. Pulse 82 p. m. Respirations 45 p. m. Profuse sweating. Indications of colicky pains. Painful efforts to defecate. Visible mucosa reddened. Respirations short and jerky.
- 4:25 P. M. Pulse 82 p. m. Respirations 40 p. m. Temperature 99.4° F. Muscular weakness.
- 4:30 P. M. Respirations 38 p. m. Sweating less profuse.
- 4:45 P. M. Pulse 70 p. m. Respirations 25 p. m. Temperature 99.8° F.
- 4:52 P. M. Defecation, copious, followed by bloody mucus.
- 5:00 P. M. Pulse 64 p. m. Respirations 18 p. m. Mucosa pale.
- 5:30 P. M. Pulse 62 p. m. Respirations 16 p. m. Defecation, followed by small quantity of bloody mucus. Cessation of sweating and of nasal discharge.
- 5:55 P. M. Defecation.
- 6:00 P. M. Pulse 62 p. m. Respirations 16 p. m. Temperature 99.8° F.

On the following morning the animal showed depression, a pulse rate of 75 p. m. the latter continuing high during the day. The subject expired at 5 P. M.

The autopsy revealed a hemorrhagic condition of the mucosa of the large intestines, while the mesocolon presented several hemorrhagic areas. Several large hemorrhagic infarcts were observed in the cortices of the kidneys. The epicardium, especially near the base of the heart showed many petechial hemorrhages. There was an intense hemorrhagic condition of the endocardium. The mucous membrane of the bladder showed some slight hemorrhagic areas.

EXPERIMENTAL HORSE NO. 3403

This healthy subject was subcutaneously injected with an extract prepared from four and a half *Gastrophilus* larvae (No. 3401) which were collected near Chicago. The larvae were crushed in a mortar, macerated for 48 hours in a physiologic salt solution at refrigerator temperature. At the conclusion of this period the mass was shaken in a mechanical shaker, filtered, and after washing the filter with more physiologic salt solution, filtered a second time.

Before the injection, the horse showed normal health. The pulse rate was 44 p. m. Respirations 16 p. m. Temperature 100.2° F. The injection was completed at 4 P. M., September 27, 1915 and the following results were noted:

- 4:20 P. M. Pulse 60 p. m. Respirations 24 p. m. Temperature 100° F. The subject became restless and began to sweat.
- 4:25 P. M. Respirations 32 p. m. Facial features distorted from time to time. The sweat commenced to drip from the animal.
- 4:33 P. M. Respirations 44 p. m.
- 4:35 P. M. Sweat dripping profusely. Mucosa congested.
- 4:40 P. M. Respirations 38 p. m. Temperature 100.2° F.
- 4:45 P. M. Respirations 40 p. m.
- 4:55 P. M. The pulse was too weak to be counted.
- 5:05 P. M. Pulse 45 p. m. Mucosa pale.
- 5:09 P. M. Respirations 40 p. m.
- 5:15 P. M. The subject showed muscular weakness.
- 5:25 P. M. Respirations 36 p. m.
- 5:30 P. M. Animal more restful.
- 6:00 P. M. Pulse 50 p. m. Respirations 35 p. m. Temperature 99.8° F.

Between 4 and 6 P. M. not less than 14 bowel evacuations were noted. On the morning following the day of injection, the pulse rate was 45 p. m., the subject was very weak and restless but showed some indications of recuperation. After another day, the appetite failed and did not return. The subject lived for 8 days after the injection

and during that time showed a temperature ranging between 99.8° F. and 103° F.

A blood count made just previous to death showed 10,215,000 erythrocytes and 95% hemoglobin. The autopsy revealed a marked enteritis and fibrinous peritonitis, gastritis, especially near the pylorus. A marked acute nephritis was present and the urine found in the bladder, post mortem, contained an abundance of albumen.

EXPERIMENTAL HORSE NO. 3422

An extract from one larva of *Gastrophilus equi* (No. 3427) was prepared in the usual manner and this was given by subcutaneous injection to experimental horse No. 3422, which before the injection showed a pulse of 40 p. m. Respirations 15 p. m. and a temperature of 99.8° F. The injection was made November 1, 1915 at 3:25 P. M. and resulted in the following reactions:

3:40 P. M. Pulse 42 p. m. Respirations 16 p. m.
 3:45 P. M. Flatus, slight colicky pains.
 3:50 P. M. Increased peristalsis. Defecation.
 4:00 P. M. Pulse 42 p. m. Respirations 20 p. m. Temperature 100.3° F.
 4:15 P. M. Pulse 40 p. m. Respirations 28 p. m.
 4:40 P. M. Pulse 44 p. m. Respirations 21 p. m. Temperature 100.4° F.
 4:53 P. M. Flatus. Defecation.
 5:03 P. M. Flatus.
 5:30 P. M. Pulse 42 p. m. Respirations 20 p. m. Temperature 100.8° F.

This animal was kept under observation until July 10, 1916 and no notable changes were observed, with the exception of the following temperature increases:

December 7, 1915.....	102.8° F.
April 6, 1916.....	101.° F.
May 17, 1916.....	101.° F.
July 2, 1916.....	101.° F.
July 3, 1916.....	101.° F.

The subject was killed July 10, 1916, the autopsy revealing numerous sub-endocardial ecchymoses as the only gross lesion to be found.

EXPERIMENTAL HORSES NOS. 3423 and 3429

Fifteen larvae of *Gastrophilus* of undetermined species were crushed and macerated for 48 hours in distilled water, while in the ice-chest. The resulting mixture, after the addition of some more distilled water was filtered through a Berkefeldt filter. The filtrate was placed in a dialyzer for 8 days. After that time both dialysate as well as non-dialysate were dried at room temperature, the drying process being hastened by means of an electric fan.

On November 18, 1915, the dried dialysate was suspended in a physiologic salt solution and the resulting suspension injected intravenously into the experimental horse No. 3423. As a result the usual marked evidence previously seen after injections of *Gastrophilus* materials were observed. There were muscular tremors, rapid respiration, great depression and profuse sweating.

Before placing the filtrate prepared from the 15 *Gastrophilus* larvae in the dialyser, a small portion of it was precipitated with 95% alcohol. After the precipitation the alcohol was filtered off, the filter again washed with alcohol and the filtrate evaporated at room temperature.

On November 8, 1915 the evaporated alcoholic extract was suspended in a physiologic salt solution and injected into experimental horse No. 3429. This injection was followed by a typical reaction.

The non-dialysate was likewise suspended in physiologic salt solution and injected intravenously in experimental horse No. 3429 on November 18, 1915. This injection was also followed by a well marked reaction, which, however, began to disappear after some 15 minutes.

Ninety small *Gastrophilus* larvae of undetermined species were crushed in a mortar, macerated in distilled water for 48 hours at refrigerator temperature. After adding some more distilled water, the material was filtered through a Berkefeldt filter and dialysed for 8 days, while in the ice-chest. Both dialysate and non-dialysate were rapidly dried at room temperature.

The dried dialysate, suspended in a physiologic salt solution was injected intravenously into experimental horse No. 3423 on November 24, 1915. As a result the subject showed a marked reaction within 2 minutes after the injection. The respiratory frequency increased, there was marked diaphoresis and defecation.

The animal died 40 minutes after the injection. The post mortem examination showed the heart to be filled with a dark liquid blood. There were ecchymoses in the endocardium, while the myocardium had a very dark color. The lungs were poorly contracted. They were distended and congested. The liver was also engorged with a liquid dark blood. The spleen, weighing 5 pounds, was dark in color, but apparently normal in texture. The intestines showed sub-peritoneal ecchymoses, especially marked near the lymphnodes of the colon. At places there were real hemorrhages in the intestinal walls. The stomach showed a severe gastritis of the pyloric portion.

The dried nondialysate, was likewise suspended in a quantity of physiologic salt solution and given to experimental horse No. 3429 by intravenous injection on November 24, 1915. This injection was not followed by any reaction.

EXPERIMENTAL HORSES NOS. 3454 and 3455.

Twenty larvae of an undefined *Gastrophilus* species, were crushed in a mortar, dried at room temperature and for 10 days extracted with absolute alcohol. Half of the resulting extract was dried at room temperature, suspended in a quantity of physiologic salt solution and injected into horse No. 3454 on December 10, 1915. The injection was not followed by any results.

Twenty larvae of an undefined *Gastrophilus* species, were crushed in a mortar, dried at room temperature and for 10 days extracted with acetone. Half of the resulting extract was dried at room temperature, suspended in some physiologic salt solution and injected into horse No. 3455 on December 10, 1915. This injection was not followed by any perceptible results.

EXPERIMENTS WITH HORSES NOS. 3429 and 3452

A consignment of 90 *Gastrophilus* larvae (No. 3444), received from Chicago, was divided into two lots, crushed in a mortar, and

macerated for 72 hours, in physiologic salt solution at refrigerator temperature. The resulting extracts were passed through a Berkefeldt filter, and one of them exposed to sterilizer heat (99°C.) for one hour, after which the precipitate formed was removed by ordinary filtration.

Samples of both lots were then subjected to protein tests with the following results:

Reagent	Raw extract	Boiled extract
Biuret	pos. red-violet	neg.
Xanthoprotein	Na yellow NH ₃ orange	neg.
Millon's	pos.	neg.
Sulphur	neg.	neg.
Molisch	pos.	pos.
Adamkiewicz	neg.	neg.
Liebermann	neg.	neg.

On December 1, 1915, an intravenous injection of 30 c. c. of the raw extract was made into horse No. 3429. Six minutes after the completion of the injection, the subject showed a marked depression with increased respiration. There was noted an increased peristalsis, resulting in four bowel evacuations. There was no sweating and 12 minutes after the injection, the horse was again in a normal condition.

The boiled extract of the 45 larvae was injected intravenously into horse No. 3452 on December 9, 1915. This resulted in a few minutes of labored breathing.

The remainder of the raw extract was also injected in a similar manner into horse No. 3452 on December 10, 1915, with apparently the same results as those following the injection of the previous day. Probably horse No. 3452 did not have the same degree of sensitiveness to *Gastrophilus* material as shown by other horses.

EXPERIMENTS WITH HORSE NO. 3455

Twenty larvae, ranging in size from half to complete larval development and collected from the stomach of horse No. 3454 were crushed, thoroughly macerated in sterile water and placed in a series of carefully tested collodion sacks suspended in sterile distilled water. The dialysation was continued for 4 days at ice-chest temperature. The total dialysate represented 500 c. c. and to this enough sodium chloride was added to render the solution isotonic to a .85% physiologic salt solution.

On March 25, 1916, this 500 c. c. dialysate was injected intravenously into experimental horse No. 3455, the injection requiring about 8 minutes. The following observations were recorded:

. When about 100 c. c. were injected the animal showed muscular tremors in the regions of both flanks, which soon were extended over almost the entire voluntary musculature. Simultaneously there was a marked decline in the arterial tension. Five minutes after the beginning of the injection the animal defecated copiously. Diaphoresis, first visible about the eyes and the nostrils, soon spread

over the entire skin and became very profuse. Mucus dripped from the nares in clumps.

Frequent bowel evacuations continued at about 12 minute intervals. The fecal material was solid at first, but changed later to a semi-liquid mush.

After about 30 minutes the blood pressure rose slightly and the animal's condition began to improve, although a depressed condition persisted for several hours. Seven hours after the injection the pulse rate was still 66 p. m.

On March 26, 1916, the pulse 60 p. m. was very weak, the respirations were markedly increased. The subject was depressed and there was no appetite. On the following day the pulse rate was still 60 p. m. and the general depression was more marked, while the appetite was still in default.

On March 28, 1916, the subject was recumbent and unable to rise. Its helpless condition required that the animal be destroyed.

Among the conditions revealed by autopsy, we note the following: The liver was very friable and showed a marked fatty degeneration. The spleen showed numerous diffuse hemorrhages throughout the parenchyma. The heart presented a few sub-endocardial ecchymoses. The kidneys were friable and showed some evidence of nephritis. The gastric mucosa was marked by a number of dollar sized hemorrhagic areas. The large and small intestines presented diffused subserous and muscular hemorrhages: Urine collected post-mortem contained albumen.

EXPERIMENT WITH HORSE NO. 3455

On April 14, 1916, this horse was given an intravenous injection of 150 c. c. of non-dialysable *Gastrophilus* extract prepared as follows: Twenty large larvae were thoroughly macerated in distilled water and placed in carefully tested collodion sacks, suspended in distilled water. Dialysis was continued for 3 weeks, during which the water surrounding the sacks was changed 3 times. The non-dialysate was passed through a Berkefeldt filter and sufficient sodium chloride was added to render the solution isotonic to an .85% physiologic salt solution. This material was injected as stated above with the following results:

10:27 A. M. Injection commenced, completed in 2 minutes.

10:29 A. M. At the termination of the injection the pulse increased from 44 p. m. to 55 p. m.

10:31 A. M. Muscular tremors in region of flanks. The subject became very restless.

10:33 A. M. The pulse was very weak, but could not be counted owing to great restlessness of the subject.

10:37 A. M. Subject very restless, walked continuously and sneezed persistently.

10:39 A. M. Pulse 72 p. m. and very weak. Bowel evacuations. Sweating began about nose, back of ears and on the sheath.

10:42 A. M. General diaphoresis. Pulse 90 p. m. and almost imperceptible.

10:45 A. M. Sweat dripping from pendant portions. Excessive lachrymation.

10:50 A. M. Pulse 84 p. m. and somewhat stronger.

All the phenomena recorded above were apparently receding. During the remaining portion of the day, the animal appeared listless, greatly depressed and during the night following became recumbent and not being able to rise, it was killed by bleeding.

The following changes were noted at the autopsy. The mucosa of the urinary bladder was diffusely hemorrhagic for about one-half of its entire area. The kidneys were very friable and nephritis was apparent. The spleen showed numerous sub-capsular ecchymoses.

The liver was apparently involved in a fatty degeneration. The lungs were slightly congested. The heart was very soft, flabby and showed diffuse sub-endocardial hemorrhages, especially in the left ventricle. Both small and large intestines, showed throughout a marked congestion in both mucosa and muscularis. The visceral lymphnodes showed slight engorgement with the exception of the gastric and splenic groups which were apparently becoming diffusely hemorrhagic. The peritoneum was markedly congested throughout. Urine collected post mortem contained albumen as well as hemoglobin.

EXPERIMENT WITH HORSE NO. 3584

On May 1, 1916, 25 larvae of *Gastrophilus*, removed from the stomach of horse No. 3455 were thoroughly crushed and macerated in about 150 c. c. of distilled water, placed in collodion sacks and dialysed in running tap water for 1 week, the temperature of the water ranging between 12 and 16° C.

On May 8, 1916, the material remaining in the dialyser was passed through a Berkefeldt filter and sufficient sodium chloride was added to render the solution isotonic to a .85% solution. This solution was injected intravenously into horse No. 3584 with the following results:

Before injection. Pulse 36 p. m., strong and full. Respiration 10 p. m.

4:50 P. M. Intravenous injection of 150 c. c. non-dialysed filtered bot extract.

4:55 P. M. Defecation. Excreta liquid mixed with pellets.

4:58 P. M. Diaphoresis appearing in region of thighs.

5:00 P. M. Defecation. Watery substance. Violent peristalsis. Slight colicky pains.

5:02 P. M. Pulse 70 p. m., very weak, irregular. Respiration 15 p. m. Diaphoresis general but not profuse.

5:05 P. M. Abundant watery bowel evacuations. Pulse 70 p. m. Weak.

5:10 P. M. Pulse 75 p. m., very weak, irregular. Sweating increasing, few drippings from pendant portions. Fecal discharge, profuse and watery.

5:15 P. M. Pulse 63 p. m., weak, sweating decreasing.

5:25 P. M. Pulse 60 p. m., weak. Respiration 12 p. m. Diaphoresis has ceased.

5:30 P. M. Recumbent.

On May 9, 1916.

8:00 A. M. Temperature 104.4° F. Pulse 64 p. m. and weak. Slight appetite.

6:00 P. M. Temperature 104.5° F. Pulse 72 p. m. and weak. No appetite.

On May 10, 1916

8:00 A. M. Temperature 99.4° F. Pulse 50 p. m. Recumbent and unable to rise. Destroyed by gun-shot.

At the autopsy the heart showed a few sub-endocardial petechiae and ecchymoses. One of the lungs was hemorrhagically suffused probably owing to stasis. The large and small intestines showed numerous sub-serous and intramuscular hemorrhages ranging in size from that of a small pin point to that of a pea, the mucosa was dotted with numerous petechiae.

EXPERIMENT WITH HORSE NO. 3615

On July 14, 1916, this horse was given a physiologic salt solution extract of 30 larvae of undetermined *Gastrophilus* species (No. 3635) prepared in the usual manner. The intravenous injection was completed at 11:15 A. M. The following observations were made:

11:17 A. M. Slight muscular tremors.

11:20 A. M. Rapid breathing, weakened pulse.

11:23 A. M. Marked diaphoresis.

11:30 A. M. The usual symptoms, following bot material injections were all well marked.

12:00 M. The disturbance was less marked, but the pulse was weak and the breathing rapid.

6:00 P. M. In apparent normal condition, appetite good, but the temperature rose to 102.4° F.

The animal continued in good health.

On July 22, 1916, the subject was given by means of the stomach tube, the extract of 92 larvae of *Gastrophilus equi* (No. 3640) without this resulting in any visible reaction.

On August 17, 1916, the subject was given an intravenous injection of 50 c. c. of a distillate prepared from 15 larvae of *Gastrophilus hemorrhoidalis* by Dr. Maurice Dolt, without any reaction following.

On August 18, 1916, this animal received an intravenous injection of 75 c. c. of the filtered residue of the material from which the distillate, used on the previous day was prepared. No reaction could be observed.

This subject was kept under daily clinical observation until October 6, 1916, when it was used for anatomy purposes. During that time the only febrile period observed, was that during the 2 days following the injection of July 14, 1916.

EXPERIMENT WITH HORSE NO. 3616

Thirty larvae of *Gastrophilus* (No. 3635), species not determined, were crushed and macerated for 16 hours in physiologic salt solution at refrigerator temperature. The extract was exposed to sterilizing heat (99°C.) for 1 hour and subsequently filtered. The clear filtrate (75 c. c.) was injected intravenously into experimental horse No. 3616 at 10:50 A. M. on July 14, 1916 with the following results:

11:00 A. M. Profuse sweating. Salivation, lachrymation, nasal mucous discharge, defecation, and violent abdominal straining. The foregoing phenomena apparently increased in intensity until

11:25 A. M. when the breathing became labored, the subject fell down and soon showed tetanic convulsions.

11:32 A. M. Respiratory failure.

11:35 A. M. Dead.

At the autopsy, all organs showed intense congestion and in some instances hemorrhagic suffusions. All mucosae and serosae were markedly engorged. Gastritis and endocarditis were especially marked. The urine collected post mortem contained no albumen.

EXPERIMENT WITH HORSE NO. 3626

Thirty larvae of *Gastrophilus* (No. 3635), of undetermined species were extracted for 16 hours in a physiologic salt solution, in the refrigerator, after having been crushed in the usual manner. The extract was exposed to sterilizing heat (99° C.) for 1 hour. The precipitate formed by the heating, was collected by centrifugation and filtration, washed in three changes of sterile physiologic salt solution and injected into experimental horse No. 3626, while mixed with 75 c. c. of physiologic salt solution. The injection was made at 11 A. M. on July 14, 1916.

The following reaction developed rather slowly:

- 11:15 A. M. Slight sweating, increased respiration, the subject becoming restless.
11:18 A. M. Marked diaphoresis. All the usual phenomena following *Gastrophilus* injections were increasing in intensity.
11:20 A. M. Subject laid down and was apparently very sick. Remained recumbent until
1:25 P. M. when it arose, rather weak, showing rapid pulse and continuing in a restless state.
6:00 P. M. Apparently normal with the exception of a temperature of 104° F.

After this the animal remained normal.

On July 22, 1916, this animal was given into the stomach an extract prepared in the usual manner from 135 larvae of *Gastrophilus nasalis* (No. 3639). No appreciable reaction followed.

On August 17, 1916, the subject received intravenously 50 c. c. of a saturated solution of phosphine, prepared by Dr. Maurice Dolt. No reaction followed.

On August 18, 1916, the subject received intravenously 75 c. c. of an extract prepared from 15 larvae of *Gastrophilus nasalis* (No. 3667) in the usual manner. The injection was made at 10:45 A. M. and led to the following results:

- 10:48 A. M. Defecation. Subject very restless and colicky.
10:50 A. M. Profuse sweating. Animal shows intense abdominal pain.
10:52 A. M. Subject fell to the floor. Cardiac failure and dyspnea.
11:08 A. M. Dead.

The postmortem examination showed the kidneys to be engorged. The spleen was marked by numerous subcapsular hemorrhages. The lungs were highly inflated and slightly congested. The heart presented very marked sub-endocardial hemorrhages. Gastritis was very intense. A pronounced congestion was observed in the intestines.

EXPERIMENT WITH HORSE NO. 3636

On July 22, 1916, this animal was given by means of the stomach tube a physiologic salt solution extract of 39 larvae of *Gastrophilus hemorrhoidalis*. (No. 3641) the injection being completed at 8:50 A. M.

- 9:10 A. M. Slight tremors of the facial muscles.
9:20 A. M. Slight increase of tremors. Very slight lachrymation.

From time to time the subject passed small quantities of flatus: peristalsis increased to low rumblings and the animal acted as if about to defecate. Nothing further was noticed up to 11:30 A. M. after which the animal was watched no further.

During the 6 weeks between the time of injection and that when the subject was killed, no temperature reaction took place. The autopsy revealed nothing that could be associated with the experiment.

EXPERIMENT WITH HORSE NO. 3657

On August 16, 1916, this subject received a subcutaneous injection of 55 c. c. of an extract prepared in the usual manner from 10 larvae of *Gastrophilus nasalis* (3667) and sterilized for 1 hour in the steam sterilizer.

At the time of injection 4:05 P. M. the pulse rate was 52 p. m. and its character rather weak.

- 4:15 P. M. Slight lachrymation, expectoration and defecation, the latter probably representing a normal evacuation.
- 4:25 P. M. Slight sweating and twitching of facial pectoral and abdominal muscles.
- 4:40 P. M. The subject became restless. Diaphoresis somewhat increased. Pulse 58 p. m. and slightly weaker.
- 5:00 P. M. Sweating more marked. A second evacuation from the bowels. This time the feces had a semi-liquid consistency. Animal appeared more restless.
- 5:15 P. M. Another liquid bowel evacuation. Sweat beginning to drip.
- 5:35 P. M. All reactions gradually increasing, perspiration becoming marked. Sweat dripping in moderate quantities from pendant portions.
- 5:55 P. M. Pulse weaker.
- 6:06 P. M. All other conditions about the same as already mentioned.

When the animal was again observed some 14 hours later, it presented apparently a normal condition.

During the 2 months the animal was under observation there was a temperature rise to 101.5° F. on August 28, 1916, one to 102° F. on September 28, 1916 and another one on September 29, 1916, when the temperature rose to 102.3° F.

The autopsy of this animal revealed nothing of a striking character. The urine was normal.

EXPERIMENT WITH HORSE NO. 3663.

Twenty-four larvae of *Gastrophilus equi* (No. 3681) were placed in physiologic salt solution and kept at a temperature of 37.5° C. for 24 hours. The fluid was then poured off, filtered and placed in the refrigerator. This was repeated every 24 hours, until, what we assumed to be the total excretions of the larvae for 72 hours had been gathered.

The mixture thus secured was given by intravenous injection to horse No. 3663 at 3:20 P. M. on August 26, 1916, with the following results:

- 3:25 P. M. Subject becoming restless.
- 3:28 P. M. Pulse faster. Slight sweating about scapular regions.
- 3:30 P. M. Defecation.
- 3:35 P. M. Beginning of urticaria. Muscular tremors made their appearance.
- 3:40 P. M. Muscular tremors general and pronounced. Pulse, very weak, 85 p. m. Urticaria very marked.
- 3:50 P. M. Semi-liquid bowel evacuations.
- 4:00 P. M. Pulse almost imperceptible, 96 p. m.
- 4:30 P. M. Pulse somewhat stronger, 85 p. m. During the preceding 10 minutes there were three watery bowel evacuations.

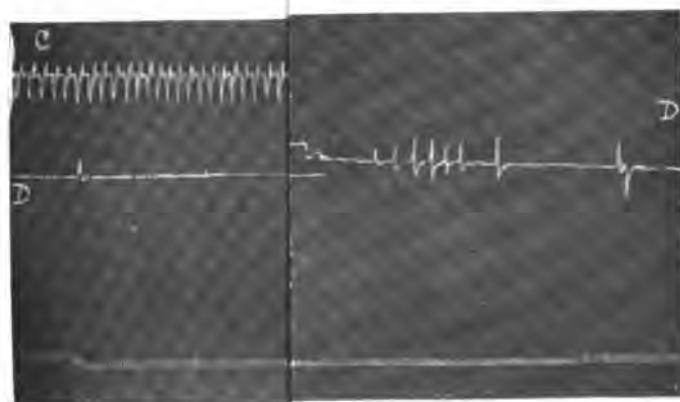
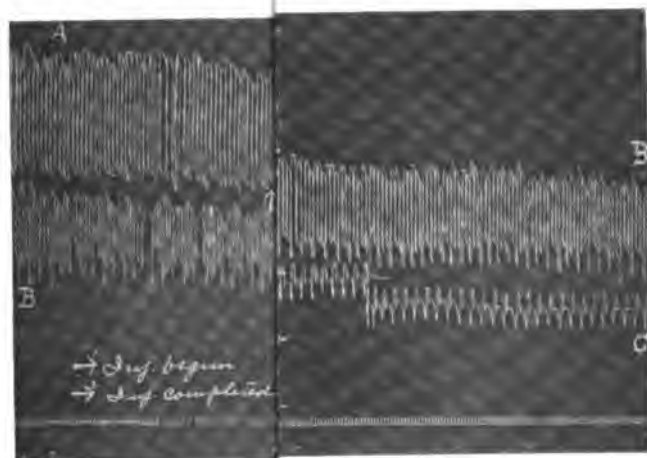
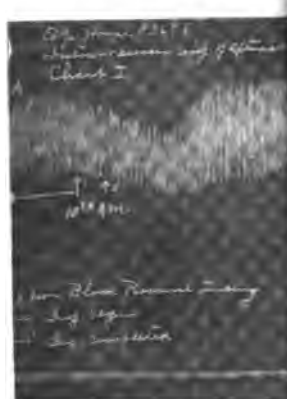
REMARKS. The usual excessive diaphoresis, lachrymation and expectorant actions were almost, wholly absent in this case. However, the effect upon muscular tissues was very marked. In the regions where the skin lies in folds it was drawn tightly in marked corrugations, the paniculus, evidently being strongly affected. Urticaria was very pronounced and continued during the time of observation.

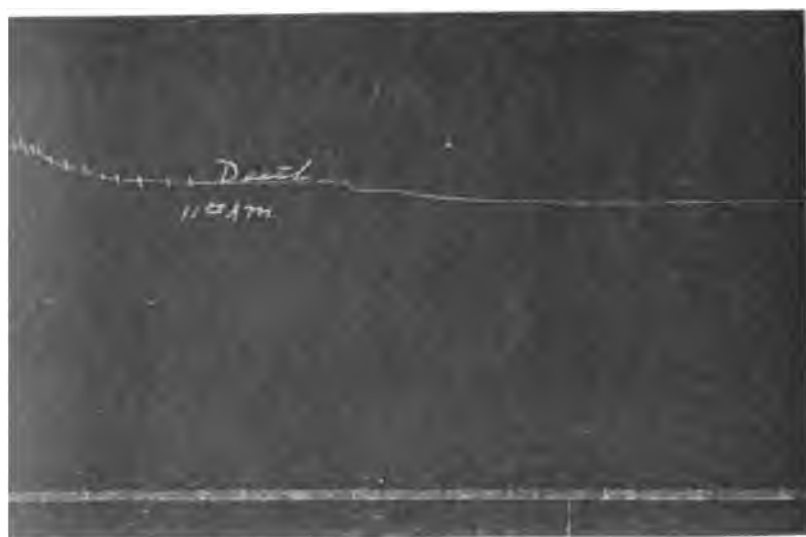
As the subject was suffering from a very painful arthritis it was killed on September 13, 1916, without having shown any febrile reaction.

The autopsy revealed nothing, which could be associated with the experiment.

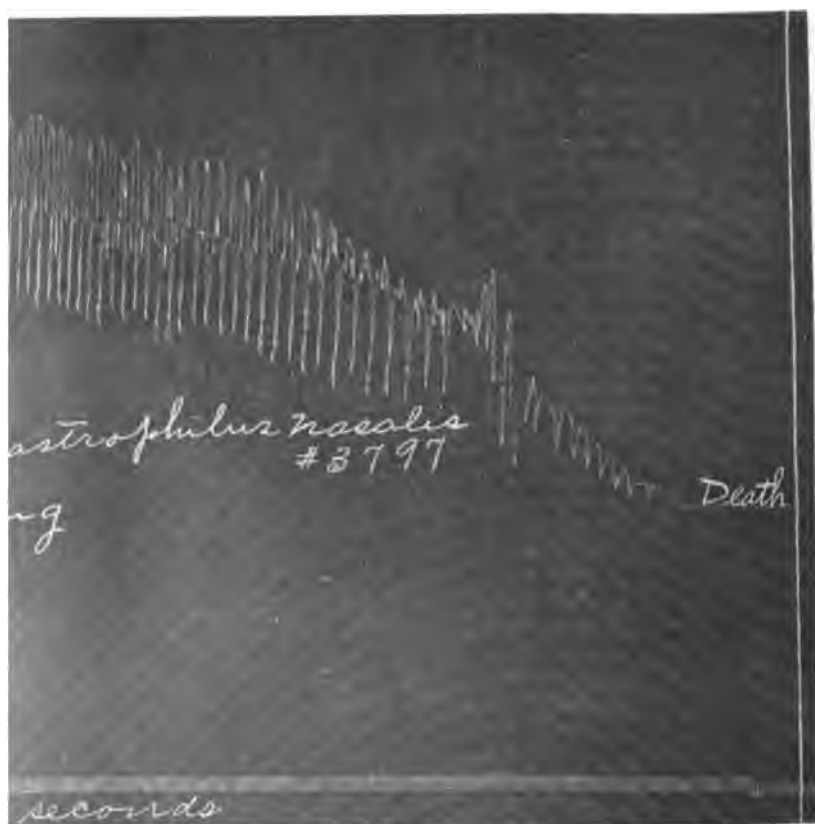
EXPERIMENT WITH HORSE NO. 3678

On August 28, 1916, the extract of 18 larvae of *Gastrophilus equi* (No. 3681) prepared in the usual manner, was given by intravenous





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injection to horse No. 3678, while the latter was under chloroform anaesthesia, for the purpose of securing a kymograph tracing of the blood pressure and heart action. This was accomplished. (See Graph No. I.)

The subject succumbed to the injection within 40 minutes. The autopsy disclosed marked subendocardial hemorrhages while a very marked gastritis was observed. All lymphnodes were more or less hyperemic.

EXPERIMENT WITH HORSE NO. 3655

On August 23, 1916, this subject, while under chloroform anaesthesia, was given 75 c. c., of a physiologic salt solution extract of 20 larvae of *Gastrophilus nasalis*. The usual diaphoresis was noted, while the effects on the circulation were recorded by a kymograph blood pressure tracing. (See Graph No. II.) The injection resulted in death.

The post mortem examination revealed a few sub-capsular hemorrhages of the spleen. The heart was marked by a few sub-endocardial petechiae and ecchymoses. There was a marked gastritis, the mucosa showing a few ulcers. The urine contained albumen.

EXPERIMENT WITH HORSE NO. 3625

This horse, after having served for some months, in another experiment was anaesthetized with chloroform on November 7, 1916, and while under the narcotic, was given an intravenous injection of a physiologic salt solution extract prepared in the usual manner from 20 larvae of *Gastrophilus equi* (No. 3755). The circulatory reaction was recorded by kymograph. (See Graph No. III.)

After the injection was completed the animal collapsed rapidly and died in 17 minutes after having shown the usual reactions seen after such injections so far as they were not masked by the narcosis.

The most notable features recorded at the autopsy were congestion of the kidneys, a high degree of inflammation of the lungs and engorgement of the gastric mucosa.

EXPERIMENT WITH HORSE NO. 3747

On December 29, 1916, while this subject was under chloroform anaesthesia, it received by intravenous injection an extract prepared in the usual manner from 18 larvae of *Gastrophilus nasalis*, in order to obtain a kymograph tracing of the circulatory reaction. The injection caused death within a very short time. (See Graph No. IV.)

The autopsy revealed a subendocardial congestion and ecchymoses. The lungs were markedly inflated, in fact more so than in any of our previous cases. There was congestion of the gastric mucosa near the pylorus. The urine showed no abnormal features.

EXPERIMENT WITH HORSE NO. 3742

This horse was given a daily dose of *Gastrophilus* material in order to determine, whether or not an anemia could be thus produced. The following are the data recorded in this experiment.

November 4, 1916 Subcutaneous injection of extract of one larva of *G. equi* (3730)
 November 6, 1916 Subcutaneous injection of extract of one larva of *G. equi* (3735)
 November 8, 1916 Subcutaneous injection of extract of one larva of *G. equi* (3735)
 November 9, 1916 Subcutaneous injection of extract of one larva of *G. equi* (3735)

- The injections were sometimes followed by evidence of uneasiness and later by abscess formation. On account of the latter the subsequent injections were made intravenously. November 10, 1916, pre-injection pulse 36 p. m. Respirations 20 p. m. Temperature 100.2° F.
- 3:25 P. M. Injection of extract of one larva of *Gastrophilus equi* (3735) followed by restlessness and defecation within 5 minutes.
- 4:00 P. M. Pulse 40 p. m. Respirations 32 p. m.
- 5:30 P. M. Pulse 60 p. m., and very weak. Respirations 28 p. m. Temperature 102° F.
- November 11, 1916. Pre-injection pulse 42 p. m. Respirations 18 p. m. Temperature 100.4° F.
- 11:15 A. M. Injection of the extract of one larva of *G. equi* (3748), not followed by a visible reaction.
- November 12, 1916. Pre-injection pulse 39 p. m. Respirations 22 p. m. Temperature 100.6° F.
- 11:20 A. M. Injection of extract of one larva of *G. equi* (3748). No visible reaction.
- November 13, 1916. Pre-injection pulse 39 p. m. Respirations 18 p. m. Temperature 100° F.
- 2:30 P. M. Injection of extract of one larva of *G. equi* (3748). No visible reaction.
- November 14, 1916. Pre-injection pulse 36 p. m. Respirations 18 p. m. Temperature 100° F.
- 2:57 P. M. Injection of extract of one larva of *G. equi* (3748).
- 3:02 P. M. Respiratory frequency increasing. Animal began to stiffen and fell to floor, remaining there for 15 minutes. Immediately after falling the pulse rate rose to 70 p. m., but was rather strong in character. In the course of a quarter of an hour it became slower and very weak. Slight twitching of voluntary muscles and three defecations followed. Temperature 100° F. No diaphoresis or lachrymation were observed. The animal soon assumed a normal condition.
- November 16, 1916. Pre-injection pulse 36 p. m. Respirations 20 p. m. Temperature 100.4° F.
- 4:20 P. M. Injection of the extract of one larva of *G. equi* (3748).
- 4:23 P. M. The animal became restless, began to totter, the musculature showed marked tetanus-like rigidity and the subject fell to the floor. The pulse increased in volume and frequency, 80 p. m., but within 10 minutes became almost imperceptible, continuing very fast. Evacuation of feces and flatus.
- 5:00 P. M. The animal regained the standing posture, and with the exception of a very weak pulse was apparently normal.
- November 16, 1916. Pre-injection pulse 42 p. m. Temperature 99.8° F.
- 3:22 P. M. Injection of extract of one larva of *G. equi* (3748).
- 3:25 P. M. The subject became stiff, began to stagger, showing tetanic spasms of the entire musculature and fell to the floor. Pulse 120 p. m. The heart beat was violent and audible several feet away. Feces and flatus were evacuated.
- 3:30 P. M. Pulse 56 p. m., weak.
- 3:35 P. M. The subject arose and but for a weak pulse, appeared normal.
- November 17, 1916. Pre-injection pulse 36 p. m. Respirations 24 p. m.
- 3:13 P. M. Injection of the extract of one larva of *G. equi* (3748). After 1 minute the subject became very restless, and the voluntary muscles commenced to show tetanic contractions. There was rigidity and trismus. The subject fell to the floor within 2 minutes after the completion of the injection. Dyspnea soon became apparent. There were violent abdominal spasms, during which urine was voided. The pulse was imperceptible, and death followed in about 6 minutes after the injection.

The autopsy revealed nothing of a conspicuous nature with the exception of a slight degree of pulmonary inflation.

Two blood counts were made in this case, one before the experiment and one after. The former revealed 7,590,000 erythrocytes and

90% hemoglobin and the latter 5,256,000 erythrocytes and 88% hemoglobin.

EXPERIMENT WITH HORSE NO. 3768

The subject received daily intravenous injections of extract prepared from one larva of *Gastrophilus nasalis* in the usual manner for the purpose of discovering if by this method anemia can be induced.

The first injection was made December 5, 1916, and this as well as the three following ones did not provoke any noticeable reaction.

December 9, 1916. Injection completed at 9:45 A. M.

10:05 A. M. Slight muscular tremors and mucous discharge from the nose.

10:15 A. M. Nasal discharge pronounced.

11:00 A. M. The reaction had ceased.

December 10, 1916. The injection was not followed by anything unusual.

December 11, 1916. The injection caused a slight discharge of nasal mucus and increase in the rate of respiration.

December 12, 1916. The injection finished at 11:30 A. M.

11:35 A. M. Mucous discharge from nose. Increase in respiratory frequency.

11:40 A. M. The subject became restless and breathed hurriedly. Defecation.

11:50 A. M. The animal again in normal condition.

December 13, 1916. The injection completed at 11:30 A. M.

11:35 A. M. Subject became restless, breathed rapidly and showed slight muscular tremors. Slight mucous discharge from nose.

11:50 A. M. The animal breathed rapidly, but otherwise was apparently normal.

December 14, 1916. The injection finished at 2:31 P. M.

After 1 minute the subject became restless and the breathing became hurried. The animal began to stagger, tottered about, showing tetanic spasms and fell to the ground 4 minutes after the injection. It lay prostrate with the limbs rigidly extended. Respirations greatly increased, both as to frequency and volume. The pulse was very fast and almost imperceptible.

3:40 P. M. The breathing became dyspneic in character, slight mucous discharge from the nose. Defecation.

3:50 P. M. Respirations more rapid, 74 p. m. Animal in chest position.

4:10 P. M. Respirations 60 p. m., not so deep. Pulse growing stronger, 66 p. m.

4:30 P. M. The subject stretched out after trying to regain its feet. Respirations 50 p. m.

4:40 P. M. The respirations became very fast and the pulse also increased in frequency and became very weak.

4:50 P. M. Dyspnea very pronounced.

4:55 P. M. Dead.

The autopsy revealed the results of an extensive hemorrhage of undefined origin, within the pelvis. The right lung showed a large fresh hemorrhagic area, while the pulmonary tissue throughout presented an enormous number of small pinhead sized hemorrhages. The heart presented extensive and marked sub-endocardial hemorrhagic suffusions.

As may be surmised the experiments with the last two horses were designed in order to determine the possibility of producing an anemia with repeated injections of bot material. The repeated injections proved, however, to be disastrous and hence we aimed to safeguard our next animal by means of greater intervals between injections as well as by the use of small desensitizing doses, in accordance with the plan of Besredka (8).

At the same time, and for the same reason, we treated another animal with repeated doses of egg white inasmuch as the anaphylactic nature of the various reactions, thus far obtained had already become

very apparent to us. The two experiments mentioned are summarized as follows:

EXPERIMENTS WITH HORSE NO. 3798

Date 1917	Material Injected	Results	Red cells	Hemo-globin percent	Remarks
Jan. 3	One larva G. Nasalis	None	6,250,000	85	
Jan. 6	One larva G. Nasalis	Slight increase in respiration			
Jan. 10	One larva G. Nasalis	None			
Jan. 15	Two larvae of same	Marked reaction lasting 10 minutes	6,570,000	80	
Jan. 22	One larva of same	Reaction			
Jan. 29	One larva of same	Very slight reaction	6,818,000		
Feb. 5	One larva of same	Slight reaction	8,107,000	85	
Feb. 12	One larva of same	Slight reaction	7,922,000	90	
Feb. 19	One larva of same	None	7,428,000	90	
Feb. 26	Two larvae of same	None	7,785,000	85	
Mch. 2	Three larvae of G. equi	Slight reaction	7,160,000	85	
Mch. 5			7,411,000	85	
Mch. 12	Three larvae of G. equi	Slight reaction			
Mch. 19	Four larvae of same	Reaction	5,681,000	85	
Apr. 2	Five larvae of same	Very slight reaction	5,296,000	75	
Apr. 9	Five larvae of same	No reaction			
Apr. 16	Five larvae of same	Very slight reaction	5,885,000	70	
Apr. 23	Five larvae of same	Very slight reaction	6,944,000	80	
Apr. 30	Five larvae of same	None	5,821,000	75	
May 7	Five larvae of same	None	5,925,000	80	
May 14	Seven and a half of same	Slight reaction			
May 21	Seven and a half of same	None			
May 24					
May 28	Ten larvae of same	Reaction	5,614,000	80	
June 4	Ten larvae of same	None	5,903,000	80	
June 7	Ten larvae of same		5,251,000	80	

On June 7 this subject was found down in its stall, and not being able to rise was destroyed by gun shot. The autopsy revealed nothing unusual, aside from a marked albuminuria.

EXPERIMENTS WITH HORSE NO. 3814

Date 1917	Egg-white injected c. c.	Results	Red cells	Hemo-globin percent	Remarks
Jan. 10			7,500,000	90	
Jan. 13	5.	None			
Jan. 18	3.	None			
Jan. 22	2.	None			
Jan. 26	1.	Slight reaction			
Jan. 29			7,602,000	90	
Jan. 31	1.	Very slight reaction.....			
Feb. 4	1.	None			
Feb. 5			7,607,000	80	
Feb. 12	1.	Very slight reaction	8,414,000	85	
Feb. 19	1.	None	7,870,000	90	
Feb. 26	1.2	Marked reaction	8,214,000	85	
Mch. 5			7,320,000	85	
Mch. 12	1.5	None	6,581,000	85	*
Mch. 19	2.	None	8,222,000	85	*
Apr. 2	3.	None	9,200,000	85	*
Apr. 9	4.	Slight reaction	9,351,000	90	*
Apr. 16	5.	Reaction	9,440,000	100	*
Apr. 23	5.	Very slight reaction.....	9,885,000	95	*
Apr. 30	5.	Slight reaction	9,355,000	90	*
May 7	5.	None	9,314,000	95	*
May 14	7.5	None			
May 21	7.5	Very slight reaction.....	10,207,000	95	*
May 28	10.	Very slight reaction.....	8,470,000	90	*
June 4	10.	Very slight reaction.....			*
June 9			8,311,000	90	
June 11	10.	Very slight reaction.....			

* Desensitization.

On June 12, 1917, this subject was given an injection of *Gastrophilus* material, which was used in another experiment for the purpose of testing its toxicity in the ordinary horse. The animal sustained a marked reaction and was destroyed while this was still in progress. The autopsy revealed nothing unusual.

The following series of experiments were designed to throw some light on the possibility of disease transmission by the blood or serum of horses, which previously had been treated with *Gastrophilus* extracts.

EXPERIMENTS WITH BLOOD AND SERUM

EXPERIMENT WITH HORSE NO. 3043

This animal was injected with 240 c. c. of fresh blood taken from horse No. 2612, 112 days after the latter had received the injection of *Gastrophilus* extract. On the 9th and 10th day after horse No. 3043 had received its injection, its body temperature began to rise until on the 11th day it reached the maximum of 104.5° F. The temperature declined on the 12th day until on the 13th it again approached the normal. On that day the subject was killed by bleeding.

The only changes found post mortem were well marked sub-endocardial ecchymoses and a slight albuminuria.

EXPERIMENT WITH HORSE NO. 3090

This horse was injected with 240 c. c. of blood serum, obtained from horse No. 3043 on the day that the latter was killed. On the 13th day after the injection the subject's temperature rose to 102.5° F. reaching 103.6° F. on the day following. No further changes were noted during the 25 days the animal was under observation.

EXPERIMENT WITH HORSE NO. 3103

This subject was injected with 240 c. c. of whole blood taken from No. 2612 on the day the latter was killed. Between the 12th and 16th days, horse No. 3103 showed a febrile reaction, during which the maximum temperature of 106.5° F. was reached. The horse became very weak and was killed by gun-shot in that condition.

The autopsy revealed the splenic lymphnodes to be enlarged and hyperemic and a few sub-endocardial ecchymoses.

EXPERIMENT WITH HORSE NO. 3415

Blood was taken from subject No. 3403, on the day of its death, or 8 days after it received the fatal injection of *Gastrophilus* material. On October 7, 1916, horse No. 3413 received 30 c. c. of serum prepared from this blood, the injection leading to the following febrile reactions:

Day	Morning	Evening
October 18, 1915.....	101.2	103.3
October 19, 1915.....	101.5	100.6
October 23, 1915.....	100.4	102.
October 24, 1915.....	103.3	106.
October 25, 1915.....	103.4	101.8
November 6, 1915.....	102.2	101.8
November 7, 1915.....	102.6	103.2
November 8, 1915.....	104.	104.5
November 9, 1915.....	104.5	104.8
November 10, 1915.....	104.4	104.
November 11, 1915.....	103.	100.4
November 22, 1915.....	102.5	103.5
November 23, 1915.....	104.2	104.
November 24, 1915.....	104.2	103.5
November 25, 1915.....	102.2	101.8
December 5, 1915.....	102.	103.
December 6, 1915.....	104.	104.2
December 7, 1915.....	105.	104.
December 8, 1915.....	103.	103.2
December 9, 1915.....	102.2	101.
December 16, 1915.....	101.2	103.
December 17, 1915.....	103.8	104.5
December 18, 1915.....	102.8	103.5
December 19, 1915.....	102.5	103.2
February 24, 1916.....	104.5	103.

The subject was permitted to live until March 25, 1916, but no further reactions were observed.

EXPERIMENT WITH HORSE NO. 3625

This subject was injected with 240 c. c. of fresh blood taken from horse No. 3422, two hundred and forty-seven days after the latter had

been injected with an extract prepared from one larva of *Gastrophilus equi*. As a result of the injection made July 15, 1916, subject No. 3625 showed the following, rather feeble temperature reactions:

Day	Temperature		Pulse	
	Morning	Evening	Morning	Evening
July 17, 1916.....	100.6	101.	33	35
July 18, 1916.....	100.8	101.6	34	36
July 26, 1916.....	100.2	101.	33	36
August 23, 1916.....	100.	101.	36	36
August 27, 1916.....	101.8	102.4	39	45
August 28, 1916.....	101.	102.5	39	45
August 29, 1916.....	101.5	101.4	40	39
August 30, 1916.....	100.	101.	38	39
September 4, 1916.....	100.6	101.	36	36
September 12, 1916.....	101.8	101.	39	38
September 14, 1916.....	100.	101.2	36	38
September 16, 1916.....	99.8	101.	36	38
September 17, 1916.....	100.3	101.2	37	39
September 18, 1916.....	100.8	101.2	36	38
September 19, 1916.....	100.8	101.2	36	38
September 20, 1916.....	100.6	101.6	36	38
September 24, 1916.....	100.2	101.5	35	38
September 28, 1916.....	99.4	101.	36	39
September 29, 1916.....	101.2	102.	39	39
September 30, 1916.....	100.2	102.5	36	38
October 5, 1916.....	101.4	101.2	38	38
October 8, 1916.....	100.2	101.	36	39
October 12, 1916.....	101.	101.4	36	40
October 15, 1916.....	99.6	101.4	36	39
October 16, 1916.....	102.4	101.3	36	38
October 17, 1916.....	101.	101.	36	36
October 18, 1916.....	101.	102.6	37	39
October 23, 1916.....	100.2	101.	35	37
October 24, 1916.....	100.5	101.	35	35
October 26, 1916.....	101.8	101.8	36	38
October 30, 1916.....	100.8	101.8	33	36

EXPERIMENT WITH HORSE NO. 3686

On September 6, 1916, this subject received a subcutaneous injection of 240 c. c. of fresh blood taken from No. 3636, which on July 22, 1916, had received in the stomach an extract prepared from 39 larvae of *Gastrophilus hemorrhoidalis*. On September 25, 1916, and September 26, 1916, the subject (No. 3686) showed a temperature rise to 101.6° F. and again on October 11 and 12, 1916, there was a febrile reaction, which reached a maximum of 104° F.

The horse was killed immediately after and the autopsy revealed numerous sub-endocardial ecchymoses and petechiae, but otherwise no striking lesions were observed.

EXPERIMENT WITH HORSE NO. 3688

On September 13, 1916, this horse was given an injection of 240 c. c. of fresh blood, taken from experimental horse No. 3663, which on August 28, 1916, had been injected with the excretions of 24 larvae of

Gastrophilus equi, eliminated during 72 hours.

Horse No. 3688 showed the following temperature and pulse reaction as a result of the injection above mentioned.

Day	Temperature		Pulse	
	Morning	Evening	Morning	Evening
September 27, 1916.....	100.4	101.	39	40
September 28, 1916.....	100.6	102.	39	42
September 29, 1916.....	103.4	104.	45	54
September 30, 1916.....	101.2	100.8	42	44
October 1, 1916.....	100.5	101.2	39	42

The subject was killed by gun-shot on October 2, 1916. The autopsy showed the spleen to be enlarged (8 pounds) slightly indurated and presenting numerous sub-capsular hemorrhages. The liver was slightly cirrhotic and in the heart a few endocardial ecchymoses were present. Albuminuria could be demonstrated.

With the data made available by the experiments reported above in more or less detail, we may attempt to compare our results with those of the Seyderhelms. A glance at those as reported shows immediately that they corresponded in many details. The severe reactions following injections with bot material as well as with a solution of the secretions of the larvae were quite identical.

Our results also confirm those of the Seyderhelms with regards to the thermostable character of the intoxicating substance. We likewise observed how horses, injected with the blood of other horses, which had sustained the reaction following injections with *Gastrophilus* material showed after a definite incubation period febrile disturbances, and how a third horse injected with the blood of such an animal would show a similar reaction.

In addition we demonstrated the dialysable character of the intoxicating substance and also succeeded in causing it to produce a slight reaction, by directly inserting it into the stomach of the experimental subject.

We failed, however, by single or repeated injections of bot material or blood from injected horses to reproduce any diseased condition similar to swamp fever or infectious anemia as we encounter the disease in our section and in the end must reject the hypothesis of the Seyderhelms, for the additional reason that if the almost ubiquitous bot fly had anything to do with the production of swamp-fever, the latter would not be confined to the rather markedly circumscribed areas, where it is now found.

The marked reactions following the injections with *Gastrophilus* material do in no way warrant the conclusion that the species used had any causal relation to the disease swamp-fever. As will appear later in this article other parasites may cause similar disturbances. In all probability the Seyderhelms never suspected the true nature of the phenomena they observed. With Carré and Vallée (9, 10) we do not deny the originality or the facile manner by which the Seyderhelms

conceived their hypothesis, but its specific burden must be rejected in the light of our experiments for the same reason that their rather questionable statement that the flies of *Gastrophilus hemorrhoidalis* after pupating in the stable soil, deposit their eggs in the same place will not be readily accepted by experienced entomologists.

Whatever the conclusion relative to the importance of the Seyderhelms observations may be, they have however, the merit not only of adding to our information regarding parasitic intoxicants, but also of suggesting experiments designed to explain their actions.

More fortunate in this respect than Carré and Vallée (9, 10), the writers never failed to precipitate the acute reactions so well described by the Seyderhelms in some of their accounts. The phenomena observed naturally led to the question relative to the manner by which they may be brought about. The following hypotheses suggested themselves, viz.: (1) Intrinsic toxicity on the part of the larvae. (2) The presence in the parasites of specific antibodies toxic to their host and (3) The anaphylactic nature of the reaction, due to the fact that the host had in some manner become sensitized during previous invasions.

The first hypothesis had to be rejected on account of the apparent non-toxicity to other animals, which we could demonstrate on many occasions and pertaining to a great variety of species. The second one is probably eliminated by the fact that reactions follow the use of boiled extracts, and by the disturbances following the injection of mere excretory substances.

The third hypothesis, however, seemed to be worthy of a more serious consideration. The anaphylactic nature of the reactions seen by the Seyderhelms, was first mentioned by Favero (11) who had repeated some of the experiments, while the writers were early struck by the similarity of the symptoms observed in their cases and those described as anaphylactic phenomena in the horse by Ciuca, (12), Briot and Dopter (13), and Briot and Dujardin-Beaumetz (14). The possibility of a real parasitic anaphylaxis was further suggested by the urticaria, violent intoxication and deaths so closely resembling anaphylaxis and observed after the escape of the fluid contained in the cysts of *Tenia ecchinococcus* into any of the body cavities through puncture or rupture.

The possibility of definitely determining the exact nature of the reactions assumed to be anaphylactic encouraged the writers to make further experiments with that object in view. For this purpose the kymographic tracings of the reactions caused in horses Nos. 3625, 3655, 3678 and 3747 were made and are hereby appended, as part of the evidence, upon which our conclusions are based.

We further acquainted ourselves with the nature of non-parasitic anaphylaxis in the horse for the purpose of comparing the various clinical manifestations.

The non-parasitic anaphylactic shock is shown by the following experiment and bears a full resemblance to some of the disturbances caused by injections of bot materials:

EXPERIMENT WITH HORSE NO. 3723

This horse was intravenously injected with doses of 5, 3, 2 and 1 c. c. of white of egg dissolved in salt solution respectively, at intervals of from 4 to 5 days. Those injections did not cause any visible reactions, and at no time did the serum of this horse acquire any precipitating qualities against the antigen used.

Three weeks after the last injection was given, the subject received intravenously a solution of the whites of 4-1-2 eggs in 900 c. c. of physiologic salt solution. The injection was made December 26, 1916, at 11:02 A. M. and led to the following results:

- At 11:03 A. M. After about 100 c. c. of the albumen solution were injected the subject showed restlessness and a slight degree of muscular rigidity. Immediately after the completion of the injection there was observed great restlessness, rapid breathing, and muscular twitching.
- At 11:06 A. M. The animal neighed and fell to the floor. The pulse was almost imperceptible and the respirations reached a frequency of 72 p. m. The subject showed tetanic contractions, especially of the flexors of the neck. There was a violent abdominal straining followed by an involuntary voiding of urine. The conjunctivae were markedly congested.
- At 11:08 A. M. The pulse was imperceptible. Respirations 54 p. m. The tetanic spasms increased in intensity.
- At 11:10 A. M. The subject in agony, showed dyspneic gasps and arching of the neck.
- At 11:12 A. M. Death.

The autopsy revealed renal congestion, numerous subcapsular hemorrhages, and a very marked hemorrhage of the myocardium. The lungs were congested throughout, and showed slight inflammation. The urine contained albumen.

While the observations above mentioned tended to confirm us in our suspicions relative to the anaphylactic nature of the phenomena witnessed, we recognized that in order to settle the question in a more absolute manner, it would be necessary to prove the innocuousness of bot materials to non-sensitized equines, which we conceived to be horses which had never harbored the *Gastrophilus* larvae.

In this section we did not deem it possible to secure any adult horse, which could have escaped the presumed sensitization, and hence we collected a number of colts, born after the bot-fly season.

While acquainted with the observations of Guyot (15) relative to the viability of the *Gastrophilus* eggs, we felt certain that in our rigorous climate, a colt born after November first, would not be liable to become bot infested until during the following season.

That we were mistaken in this respect the following account of the colt experiments will show.

EXPERIMENTS WITH COLT NO. 3863

This was a normal colt, born November 4, 1916. On March 3, 1917, the subject received by intravenous injection an extract prepared from five larvae of the *Gastrophilus* equi.

The colt reacted to this injection in the manner characteristic of the ones previously observed in adult horses. The subject was killed by bleeding at a time when death due to the reaction seemed inevitable.

The autopsy brought to light 75 well developed larvae of the *Gastrophilus* equi firmly attached to the gastric mucosa.

EXPERIMENT WITH COLT NO. 3891

This colt was born some time during December, 1916, when a snow storm was in progress.

On April 2, 1917, the subject received by intravenous injection the extract prepared from five larvae of the *Gastrophilus equi*. A typical and very severe reaction resulted and again the autopsy showed the presence of 20 bots of *Gastrophilus equi* in the stomach.

EXPERIMENTS WITH COLT NO. 3898

This animal was born February 2, 1917, and on April 2, 1917, was injected intravenously with the extract prepared from five larvae of the *Gastrophilus equi*.

The injection was made at 2:30 P. M.

At 2:33 P. M. The colt became restless, scratched its nose, jumped about and showed increased respiratory efforts.

At 3:36 P. M. The subject began to sweat, respiration still further increased, the animal very excited, continually thrusting its nose in the bedding. There was a slight lachrymation.

At 2:40 P. M. The subject laid down, but immediately jumped up again and began to run about. The diaphoresis remained slight.

At 3:05 P. M. All the above phenomena were receding.

The animal was killed by a strychnine injection immediately after it regained the normal state and the autopsy failed to bring to light any *Gastrophilus* larvae.

EXPERIMENT WITH COLT NO. 3906

This subject, born March 19, 1917, received on April 13, at 1:21 P. M. an intravenous injection of an extract prepared in the usual manner. This injection was followed by the following results:

At 1:23 P. M. The colt became restless, pawed, shook its head and walked about. After 2 or 3 minutes slight muscular tremors in the flank regions were observed. A slight restlessness continued. The subject drew its hind limbs up to its abdomen. Pulse 90 p. m.

At 1:30 P. M. The pulse is slightly weaker and the short haired parts of the skin slightly warmer, and moist. Evacuation of solid feces, followed by a similar one some 10 minutes later.

At 1:50 P. M. Evacuation of semi-liquid feces. The subject was slightly restless and bit at itself as well as its companions. Respiration was only slightly increased.

At 2:00 P. M. Passage of very liquid feces.

2:15 P. M. Rubbed its nose, pawed. Pulse 114 p. m. and weak.

2:50 P. M. All reactions had ceased.

On June 12, 1917, along with two other colts to be described next, this same subject, No. 3906, received an intravenous injection of 25 c. c. of a 10% extract of the larvae of *Gastrophilus equi*. The injection was complete at 3:17 P. M.

3:20 P. M. There was rapid breathing, defecating and slight colic.

3:28 P. M. The fast breathing continued and a slight discharge of nasal mucus was observed.

3:30 P. M. The colt has a coughing spell.

3:35 P. M. Continuation of the rapid breathing.

4:46 P. M. All traces of the reaction have disappeared.

The colt was killed by gun-shot immediately after the experiment. The autopsy did not disclose the presence of any larvae of *Gastrophilus*.

EXPERIMENT WITH COLT NO. 3905

A healthy colt born during the end of February or the beginning of March, 1917, and received at the station April 11, 1917.

On June 12, 1917, this subject received an intravenous injection of 25 c. c. of a 10% extract of the larvae of *Gastrophilus equi*. No reaction followed. Thirty-seven minutes later 25 c. c. of a 10% extract of the larvae of *Gastrophilus nasalis* were similarly injected. No reaction was produced.

On the following day the colt was killed and no larvae of *Gastrophilus* could be found.

EXPERIMENT WITH COLT NO. 3904

A healthy colt, born during the end of February or the beginning of March and received at the station April 11, 1917.

On June 12 this animal received by intravenous injection 25 c. c. of a 10% extract prepared from larvae of *Gastrophilus equi*. The injection was not followed by any visible reaction.

Thirty-seven minutes later the subject received an intravenous injection of 15 c. c. of a 10% extract of larvae of *Gastrophilus hemorrhoidalis*, without any reaction following.

The colt was killed on the following day and no *Gastrophilus* larvae were found.

CHECK EXPERIMENT WITH HORSE NO. 3814

In order to ascertain the intoxicating properties of the extract used in the colt experiments of June 12, 1917, this subject, which had served in an experiment previously reported, was also given by intravenous injection 25 c. c. of the same 10% extract prepared from the larvae of *Gastrophilus equi*. The injection was made at 4:28 P. M.

Within one and a half minutes after the injection the subject showed heavy breathing, lachrymation, facial distortion, a discharge of nasal mucus and defecation.

4:31 P. M. Marked diaphoresis, very labored respiration, profuse discharge of nasal mucus, tenesmus, defecation.

4:35 P. M. The marked discharge of nasal mucus was streaked with blood and the sweat was dripping from the body.

As the reaction presaged a fatal termination the subject was destroyed by gun-shot.

Reviewing the colt experiments reported above, we find that the severe reactions obtained in Nos. 3863 and 3891 could perhaps be explained by the sensitization brought about by the *Gastrophilus* larvae of which the two subjects were the hosts. It was incidentally shown that viable *Gastrophilus* eggs may be present long after the flies cease to exist, as was already observed by Guyot (15).

The reaction obtained in colt No. 3898 was more puzzling because no bots were found in the animal. In interpreting the results in this animal, it was thought that unless the *Gastrophilus* material contained an intoxicant per se, the reaction must be attributed to either an active sensitization by *Gastrophilus* embryos yet so small as to escape our observation or to a passive sensitization conferred by the mother's milk, considering the fact that this subject was used within a few days after being removed from its dam.

When therefore the injection with bot material into colt No. 3906, also precipitated a reaction, it was deemed wise not to kill this animal but to keep it alive for a sufficient time to permit any larvae or embryo which may have been responsible for the sensitization to grow to such a size as to no longer enable them to escape observation.

That this colt reacted upon the second injection some two months later was according to expectation, assuming that at any rate the first injection would have left the subject anaphylactically sensitive.

When planning the experiments with colts Nos. 3905 and 3904 we aimed to postpone the bot injections for at least 8 weeks after removing the colts from their dams in order to escape the results of a possible passive anaphylaxis through the milk from the mares, which could hardly fail to be sensitized by the parasites themselves.

For the 8 weeks preceding the injection those colts were fed with modified cow's milk as well as with such grain, hay or green feed as could be supplied in addition.

Apparently we were successful in avoiding any disturbing factor in this experiment, and to prove that in colts, not sensitized by the parasites themselves, *Gastrophilus* extract, proven to be highly intoxicating by control experiment (No. 3814) was borne with impunity. *Gastrophilus* extracts thus do not contain a specific toxic or pathogenic substance, but behave exactly like any other foreign antigen could be expected to act in an animal previously sensitized to it.

As our observations and experiments apparently justified us in the belief that at least one type of parasite sensitized its host in the sense of anaphylaxis, it became a matter of interest to determine if the same would be the case with parasites in general.

We availed ourselves thus of such opportunities as offered themselves and record our results as follows:

EXPERIMENT WITH *ASCARIS MEGALOCEPHALA*

This subject No. 3677 which had been used in a number of other experiments had always proven to be highly sensitive to the anaphylactic poison.

On April 4, 1917, at 10:39 A. M. this animal received by intravenous injection a physiologic salt extract of five specimens of *Ascaris megalocephala*.

Within less than 1 minute after the injection the horse became restless, commenced paw, strained and had a bowel evacuation of solid and flatulent materials. Simultaneously there developed profuse lachrymation and salivation.

10:42 A. M. The animal showed difficulty in breathing and fell to the floor.

Profuse sweating ensued and the peripheral veins became greatly distended. The pulse was imperceptible.

10:43 A. M. The subject gasped for air, showed violent abdominal straining and slight muscular tremors.

10:44 A. M. The animal was dead.

The autopsy revealed marked congestion of the mucosa of the bladder. The renal cortices were slightly engorged. There were profuse and very marked sub-epicardial and sub-endocardial hemorrhages distributed over all parts of the heart. The lungs were markedly inflated and presented approximately five times their nor-

mal size. It must be observed however, that this animal had shown some evidence of being affected with "heaves".

EXPERIMENT WITH TRICHODECTES PARUMPILOSUS

An aged subject No. 3815 heavily infested with lice (*Trichodectes parumpilosus*.) From 1200 to 1500 of the lice were taken from this animal, crushed and macerated in physiologic salt solution for 24 hours at refrigerator temperature. The resulting extract was then filtered through a bit of cotton and on January 12, 1917, it was injected intravenously into horse No. 3815, while at the same time some of the extract was instilled in one of the animal's eyes and four cavia received each a subcutaneous injection of .5 c. c. of the same material.

The application to the eye led to no appreciable result and the four cavia suffered no inconvenience from the injection, but the horse presented a very striking reaction.

The injection was completed at 3:01 P. M., while the pulse showed a frequency of 42 p. m. and the respiration one of 18 p. m.

Within 2 minutes after the injection the subject showed increase in the respiratory frequency and in that of the pulse. There were muscular twitchings, attempts at defecation and lachrymation.

3:06 P. M. A profuse discharge of nasal mucus manifested itself. Defecation.

3:10 P. M. Diaphoresis. Abdominal straining. Rectal mucosa protruding from the anus. Dilated nostrils.

3:15 P. M. Diaphoresis more general and profuse. Lachrymation and nasal discharge continue in a marked manner. Pulse very fast and almost imperceptible.

3:20 P. M. The respiratory frequency increases. Pulse imperceptible. Nasal discharge continues. Frequent defecations. Perhaps a slight reduction in the sweating.

3:30 P. M. Respirations 52 p. m.

3:35 P. M. When attempting to lie down the animal fell to the floor and lay prostrate. Respirations 60 p. m.

3:45 P. M. The subject passed large quantities of very bloody liquid feces. Diaphoresis, nasal discharge and lachrymation had practically ceased.

4:05 P. M. The horse arose and passed more bloody feces.

4:10 P. M. Subject again fell, laid prostrate, groaned and passed more bloody feces.

4:20 P. M. The subject rose once more. Violent expulsion of a copious quantity of bloody, liquid feces. Respirations 48 p. m. The pulse remains imperceptible.

4:30 P. M. The animal again laid down. Bloody liquid passing involuntarily from the rectum.

The subject continued weak and apathetic until death which occurred during the afternoon of January 13, 1917.

The autopsy revealed a soft and flabby heart with numerous endocardial petechiae in the left side. The mucosa of the bladder showed hyperemia and petechiae. The gastric mucosa presented a few small eroded areas and that of the intestines was marked by a few small hemorrhages.

EXPERIMENTS WITH TOXASCARIS LIMBATA

A number of these nematodes were weighed, crushed in a mortar, macerated for 24 hours in ten times their weight of physiologic salt solution, centrifuged filtered and preserved by the addition of a few drops of chloroform. On May 31, 1917, a number of dogs were injected with this extract, with the following results:

DOG NO. 4046

The subject received 1 c. c. of the *Toxascaris* extract by intravenous injection.

In about 3 minutes the dog vomited, wandered about aimlessly, showed increased respirations and in about 5 minutes defecated. Animal then laid down for a few minutes, showed a relaxed facial expression and when forced to move presented a slight degree of incoordination.

The autopsy revealed this dog to be infected with a number of specimens of *Belascaris marginata* and one of *Dibothriocephalus latus*.

DOG NO. 4047

This young and vigorous bull dog received an intravenous injection of 1 c. c. of the *Toxascaris* extract.

In about 2 minutes the subject vomited, appeared somewhat depressed, but soon improved, and had apparently recovered in the course of 10 minutes.

No parasites were found at the autopsy.

DOG NO. 4048

This dog received by intravenous injection 1 c. c. of the *Toxascaris* extract.

In about 2 minutes the subject walked about restlessly, then vomited, defecated, and laid down. After 5 minutes the animal had apparently recovered.

No parasites were found during the autopsy.

DOG NO. 4049

This subject received an intravenous injection of 1 c. c. of the *Toxascaris* extract. Not the least reaction became manifest.

The dog contained no parasites.

DOG NO. 4050

This dog received 1 c. c. of the *Toxascaris* extract intravenously, without its causing any reaction.

No parasites were found at the autopsy.

DOG NO. 4051

This animal received intravenously 2 c. c. of the *Toxascaris* extract.

In less than 2 minutes, the dog showed a marked tenesmus and stranguria, followed by frequent defecations which were almost continuous. The evacuation soon assumed a semi-liquid character. Later the animal began retching, which terminated in vomition. Defecations continued.

When the subject was forced to move, it walked with a very staggering gait, almost losing its balance.

The animal laid down after about 10 minutes, remained prostrate, breathing heavily and refused to arise when disturbed. It remained in that condition for more than 1 hour after which it arose and slowly recovered.

EXPERIMENTS WITH *BELASCARIS MARGINATA*

The worms were weighed, crushed in a mortar, macerated for 24 hours in ten times their weight of physiologic salt solution, centrifuged, filtered and preserved by the addition of a few drops of chloroform.

On May 21, 1917, and on June 16, 1917, this extract was administered to a number of dogs with the following results:

DOG NO. 3954

This subject received by intravenous injection 2 c. c. of the *Belascaris* extract. No visible reaction could be observed. The autopsy disclosed the absence of parasites.

DOG NO. 3955

This dog received an intravenous injection of 2 c. c. of the *Belascaris* extract.

Within one-half minute the subject began to vomit, showing extreme nausea, and fell to the floor. After 1 minute the animal defecated and showed dyspneic breathing.

The subject remained in this condition for three-quarters of an hour, showing during this time, salivation, marked lachrymation, nasal mucous discharge and passing bloody feces. At the end of this period the subject arose, walked with a staggering gait and began to retch and again passed bloody feces. The breathing remained panting.

One and a half hours later, the animal moved about in a restless manner, and at that time showed a heavily congested conjunctiva. On the following morning the subject was found to be dead.

The autopsy disclosed a marked gastro-enteritis with free hemorrhage in the lumen of the canal. The heart was soft and flabby, but showed no ecchymoses or hemorrhages. The lungs were well collapsed and but slightly congested. The other organs were normal in appearance.

No parasites could be found.

DOG NO. 3956

This animal received by intravenous injection 2 c. c. of the *Belascaris* extract.

In about 1 minute the subject began to run about, as if looking for a place to vomit, commenced to stagger and fell to the floor about 2 minutes after the injection.

After 6 minutes the dog vomited and defecated while showing rapid breathing. The animal remained prostrate.

Some 14 minutes later the subject vomited and evacuated a bloody semi-liquid feces. When an attempt was made to cause the dog to walk, it fell from side to side as if in a semi-paralyzed condition.

After 10 minutes more the pulse became very weak and the dog could not maintain its balance.

Fifteen minutes after this the animal panted, could walk only with difficulty and made occasional attempts at defecation.

This subject died during the night.

At the autopsy it was found that the stomach and intestines were slightly congested and that the heart presented well marked sub-endocardial petechiae and ecchymoses. The lungs were well collapsed. The other organs presented a normal appearance. No parasites were found.

DOG NO. 3957

This dog was given 2 c. c. of the *Belascaris* extract by intravenous injection.

In about 1½ minutes the animal began running about howling as if in distress. It soon commenced to stagger and lost all control of the right front leg. Retching and vomiting soon followed. The subject fell to the floor with a weak pulse and a very rapid and labored respiration.

The subject defecated and again vomited 10 minutes after the injection.

10 minutes later the dog made an attempt to walk, but could not maintain himself in a standing posture. At this time the animal passed semi-liquid bloody feces.

After 15 minutes more pure blood was ejected per anus, the act being accompanied by severe tenesmus.

20 minutes later more blood was passed and the rapid breathing continued.

25 minutes after this the animal was very restless. The subject died during the night following the experiment.

The autopsy showed a very marked gastro-enteritis throughout the entire intestinal tract. There was a free hemorrhage in the peritoneal cavity. The heart showed marked sub-endocardial hemorrhages. The lungs were well contracted and showed marked congestion. The kidneys presented hemorrhagic infarcts throughout. The mucosa of the bladder was markedly congested. No parasites could be found.

DOG NO. 4113

This dog received an intravenous injection of 2 c. c. of the *Belascaris* extract. No visible reaction followed.

Twenty minutes after the first injection 2.25 c. c. of the same extract was given in a similar manner. No reaction resulted.

The autopsy revealed a very heavy infestation with *Tenia serrata*.

DOG NO. 4112

This subject received by intravenous injection 1 c. c. of the *Belascaris* extract.

In about 2 minutes after the injection the dog showed restlessness, attempted to vomit, laid down in a corner, became very depressed and remained in this condition for about 10 minutes with occasional retchings and defecations.

Vomiting again occurred 12 minutes later, but after 20 minutes more the animal appeared to have recovered.

About one-half hour after the first injection this animal was given 2.25 c. c. of the same extract but no second reaction followed. No autopsy was made.

DOG NO. 4114

This animal received by intravenous injection 1 c. c. of the *Belascaris* extract.

Within 1 minute the animal began to retch, showed rapid breathing, soon laid down, remaining very quiet only showing an occasional sign of tenesmus.

After 10 minutes the pulse was almost imperceptible. When aroused the animal walked with great difficulty and marked incoordination of movements. The dog soon fell to the floor and remained very quiet with an imperceptible pulse. The subject died in this position 35 minutes after the injection.

It was observed that the period of rapid breathing was very brief in this dog, and during the last half of the experiment the breathing became shallow and depressed.

The autopsy showed a marked enteritis with about 100 c. c. of blood free in the lumen at the intestine. There was a slight gastritis in the region of the fundus. All internal organs showed venous stasis such as is seen in cardiac failure. The lungs were not inflated but showed venous congestion.

EXPERIMENTS WITH *DIPYLIDIUM CANINUM*

A quantity of those tape worms were weighed, crushed in a mortar, macerated for 24 hours in ten times their weight of physiologic salt solution, centrifuged, filtered and preserved by the action of a little chloroform.

On May 18, 1917, June 1, 1917 and June 14, 1917, certain dogs

were injected with a quantity of this extract with the following results:

DOG NO. 3950

This subject received by intravenous injection 4 c. c. of the *Dipylidium* extract. No reaction followed. No parasites were found at the autopsy.

DOG NO. 3951

This dog received an intravenous injection of 2 c. c. of the *Dipylidium* extract.

In 6 minutes there was observed, trembling, straining and defecation. 5 minutes later, there was another bowel evacuation, with abdominal straining. The pulse was weak and the animal showed discomfort. After 5 more minutes the subject still strained and passed some flatus. 2 minutes later the pulse was imperceptible, while some increase in the respiration was noted, accompanied by salivation.

The autopsy brought to light one specimen of *Toxascaris limbata*, but no other parasites.

DOG NO. 3952

This animal received an intravenous injection of 2 c. c. of the *Dipylidium* extract. No reaction followed. No parasites were found in this subject.

DOG NO. 3953

This subject received an intravenous injection of 2 c. c. of the *Dipylidium* extract. No reaction resulted. No parasites were found during the autopsy.

DOG NO. 4046

This animal received by intravenous injection 3 c. c. of the *Dipylidium* extract. No reaction followed. The autopsy disclosed the presence of two specimens of *Belascaris marginata* and one of *Dibothriocephalus latus*.

DOG NO. 4047

This dog received an intravenous injection of 3 c. c. of the *Dipylidium* extract. No reaction resulted. No parasites were found at the autopsy.

DOG NO. 4048

This subject was given an intravenous injection of 3 c. c. of the *Dipylidium* extract. No reaction followed. The autopsy disclosed absence of parasites.

DOG NO. 4049

This dog was injected intravenously with 3 c. c. of the *Dipylidium* extract. No reaction followed. No parasites were found during the autopsy.

DOG NO. 4050

This subject received an intravenous injection of 3 c. c. of the *Dipylidium* extract. No reaction followed.

The autopsy did not disclose parasites in this dog.

DOG NO. 4051

This dog was intravenously injected with 4 c. c. of the *Dipylidium* extract. No reaction resulted. The autopsy disclosed a large number of the *Dipylidium caninum*.

DOG NO. 4118

This animal received by intravenous injection 7 c. c. of the *Dipylidium* extract. No reaction resulted. The autopsy disclosed a heavy infestation by *Tenia serrata*.

DOG NO. 4119

This subject was injected intravenously with 15 c. c. of the *Dipylidium* extract. No reaction followed. The dog contained one specimen of *Toxascaris limbata*.

EXPERIMENT WITH *TENIA SERRATA*

A considerable number of those tape worms were weighed, crushed and macerated for 24 hours in ten times their weight of physiologic salt solution, centrifuged, filtered and preserved by the addition of a few drops of chloroform.

On June 21, 1917, the following experiment was made:

DOG NO. 4126

This dog received an intravenous injection of 5 c. c. of the *Tenia* extract.

Within 2 minutes the animal became shy, hid away in a corner and commenced to salivate and to breathe rapidly. The dog remained perfectly quiet for about 10 minutes during which the salivation continued, although the exaggerated breathing rapidly diminished. After about 12 minutes the animal arose in an apparently normal condition.

The autopsy disclosed the presence of one specimen of *Toxascaris limbata*.

At the same time when the dog No. 4126 was injected, three rabbits were given respectively intravenous injections of the same extract in quantities of 1, 2 and 3 c. c.

Within 1 minute after the injections all three of those animals commenced to sneeze, which continued for about 1 minute. The respirations increased markedly and the rabbits soon laid down in a semi-paralyzed condition and remained there for about 10 minutes. After being induced to arise, the animals could not hop in the manner of rabbits, but walked with a staggering gait.

They apparently soon recovered, but yet one of the animals died during the following night.

The autopsy disclosed in one of the rabbits two or three small cysts situated in the abdominal cavity in the sub-lumbar region. These were identified as *Cysticercus pisiformis* by Dr. B. H. Ransom of Washington, D. C.

Two caviae injected each intraperitoneally with 3 c. c. of the same extract showed no reaction whatever.

EXPERIMENT WITH *GYROPUS OVALIS* AND *GYROPUS PORCELLI*

On June 14, 1917, eight caviae, some of which were infested with the lice mentioned, were injected with extracts prepared from those parasites.

No results followed, but it must be observed that the extracts, prepared in a rather loose manner, were very weak.

Although in this series of experiments, we had no opportunity of making control injections in animals known to be non-sensitized, as we did in the colt experiments with *Gastrophilus* extract, the

writers cannot escape the conclusion, that the reactions witnessed were truly of an anaphylactic nature.

In the horse experiments the similarity between the reactions caused by *Trichodectes* and *Ascaris*, and those produced by *Gastrophilus* was quite marked, while the symptoms seen in our canine material bear so striking a resemblance to those so clearly described by Biedl and Kraus (16) that any other conclusion is scarcely possible.

In this conclusion we are further strengthened by the fact that the materials used, in so many cases failed to produce intoxication, a circumstance which serves to indicate that the substances used were in themselves innocuous.

In view of the almost universal distribution of some of the parasites used, perhaps a larger number of reactions should have been induced. This is especially so in the case of the *Dipylidium* experiments, because this parasite is one of the most commonly found in our section. In connection with the default of many reactions we must however, recognize that there may be vast differences in the manner and degree of host sensitization by parasites, while on the other hand there is no reason to believe that our extracts were prepared in the manner and concentrations capable of securing the best results. Our pharmaceutical methods were certainly more tentative than final, and with the accumulation of further knowledge they should in time become more refined.

In regard to the one experiment with *Tenia serrata* in a dog and rabbit, the writers could not accept the reactions witnessed as evidence of anaphylaxis without some further experiments but certainly regard the phenomena as highly significant.

Reviewing the results of this series in the light of our *Gastrophilus* experiments, we have no doubt of the anaphylactic nature of the reactions seen, as well as of the acute parasitic intoxications reported by Stazzi, Piana and Belfanti (17) and others.

In a letter received about a year ago from our colleague Seymour Hadwen, he was kind enough to make the writers acquainted with an interesting discovery made by him, and which apparently showed how in infested animals, parasitic extracts caused local reactions seemingly of an allergic nature, when brought in contact with certain mucosae. Subsequently Hadwen's discovery was described in an interesting article. (18)

In order to ascertain if *Gastrophilus* material has any irritating qualities, or is capable of producing allergic reactions in presumably sensitized animals and others as suggested by Hadwen, certain observations were made relative to the ophthalmic or intradermal application of the extract.

The material was prepared in the following manner. Ten larvae of each of the *Gastrophilus equi* and *nasalis* were crushed and mixed with 40 c. c. of physiologic salt solution. The two lots were then mixed, filtered through cotton and heated for 1 hour at 60° C.

The eye test made November 2, 1916, at 3:45 P. M., consisted of the instillation into one eye of each animal of a few drops of the

extract by means of a camel's hair brush. The following are the details of the experiment.

Animal	Results
Horse No. 2981	Five minutes after the instillation, lachrymation could be observed, which became profuse after 10 minutes. Marked swelling of the conjunctivae. On the morning following, lachrymation had ceased. The swelling was reduced and a small amount of thickened exudate had gathered in the corner of the eye.
Horse No. 3625	Intense lachrymation within 3 minutes. In 5 minutes the conjunctiva became swollen. At 5 P. M. the swelling was very marked, but the tear flow was diminishing. The following morning there was reduction of the swelling, and an accumulation of exudate in the corner of the eye.
Horse No. 3677	There was profuse lachrymation within 4 minutes after the application of the extract. In 15 minutes the tears were pouring down the face in four streams. There was marked swelling of the eyelids. At 5 P. M. the eye was nearly closed, but the tear flow was lessening. The subject appeared depressed and dejected. The next day a slight swelling still remained, lachrymation had ceased, and the corner of the eye showed a clump of exudate.
Horse No. 3722	There was a slight lachrymation in about 10 minutes. After 15 minutes the tear flow increased, becoming profuse in 30 minutes. The eyelids were only slightly swollen. At 5 P. M. there still was some flow of tears, but the swelling was but slight. On the following morning there still was a little swelling and a small amount of exudate.
Horse No. 3723	Lachrymation gradually began to show after about 20 minutes, increasing for something like 30 minutes. At 5 P. M. the flow of tears was fairly marked, but no swelling appeared in this case. There still was some lachrymation but otherwise the eye appeared normal on the following morning.
Horse No. 636	Not a trace of reaction.
Experimental horse, artificially infected with swamp fever in 1908, being kept in the stable continually since that time.	
Horse No. 3742	This subject showed a slight lachrymation in about 15 minutes, which continued but moderately until 5 P. M. The morning following a small amount of exudate showed in the corner of the eye, which otherwise was normal.
Horse "Babe"	The subject was not observed until 5 P. M. when it showed a moderate degree of lachrymation, of which all traces had disappeared on the following day.
Horse "Daisy"	Not observed until 5 P. M. when it presented evidence of a marked reaction with profuse lachrymation and swollen tissues. The subject appeared depressed and dejected. On the following morning the eyelids were still slightly swollen and a clump of muco-pus occupied the corner of the eye.

On November 13, 1916, the same extract was used in an eye test applied to other species of animals with the following results:

Animals	Results
Eight bovines	No reaction.
Four goats	No reaction.
One sheep	No reaction.
Twelve rabbits	No reaction.
Twelve caviae	No reaction.
Three dogs	No reaction.
One cat	No reaction.

The intradermal tests were made with *Gastrophilus* extract prepared in the usual manner and heated at 60° C. for 2 hours. About 1 c. c. was injected into the skin on the side of the neck.

The following results were recorded:

Animal	Results
Horse No. 3747	November 9, 1916. Injection at 2:50 P. M. 3:00 P. M. Very slight swelling. 3:05 P. M. Swelling 2 c. m. in diameter. 3:15 P. M. Swelling 3 c. m. in diameter. 3:30 P. M. Swelling same in diameter. 4:00 P. M. The swelling was settling below point of injection. 5:30 P. M. The swelling had not changed. November 10, 1916. 8:00 A. M. The swelling had gravitated about 5 c. m. below the point of injection, becoming thicker at farthest point, where the skin had become about 1 c. m. thick. 12:00 M. There was no change in the swelling. 5:00 P. M. The swelling was becoming smaller. On November 11, 1916. 8:00 A. M. The swelling had disappeared.
Horse No. 2981	November 10, 1916. Injection made at 3:22 P. M. 3:30 P. M. Very slight swelling. 4:00 P. M. The swelling was about 2.5 c. m. in diameter and .5 c. m. in thickness. 4:30 P. M. The swelling measured 3 c. m. in diameter and 1 c. m. in thickness. 6:00 P. M. The diameter of swelling increased to 3.5 c. m. November 11, 1916. 8:00 A. M. The diameter of swelling was 5 c. m. while the thickness was 1.5 c. m. The enlargement is very sensitive to the touch. 12:00 M. The condition was unchanged. November 12, 1916. 9:00 A. M. The swelling decreasing. November 13, 1916. 9:00 A. M. The enlargement has practically disappeared.
Horse No. 3677	November 10, 1916. Injection made at 3:20 P. M. 3:35 P. M. The subject showed restlessness, increased respirations and was pawing with colicky pains. 3:40 P. M. Evacuation of semi-liquid feces. Diaphoresis became marked. Subject very restless. 3:45 P. M. Pronounced sweating. Marked lachrymation, which seemed to be more profuse from the eye which had previously served for the ophthalmic test. Respirations 54 p. m. The subject coughed and rubbed itself frantically on both sides of the stall.

Animal

Results

N. B.—At no time was a noticeable swelling observed at the point of the injection.

- 3:50 P. M. The horse pawed violently. There were two rather soft evacuations within 5 minutes. The coat was moist and hot with sweat. The animal coughed very forcibly and expectoration was manifest. Temperature 100° F.
- 4:00 P. M. There were two fecal evacuations with frequent passage of flatus. Pulse weaker.
- 4:10 P. M. Colicky symptoms prevailed, but diaphoresis, expectoration and lachrymation decreased in intensity. Respiration 50 p. m. were exaggerated and violent. More evacuation of liquid feces.
- At 4:35 P. M. The exaggerated breathing persisted, but otherwise the reaction was lessening in severity. Two liquid evacuations. Temperature 99° F.
- 4:45 P. M. The animal laid down, arising again in 5 minutes. The exaggerated breathing continued.
- 5:00 P. M. Temperature 99.4° F. The skin was dry and the reaction had ceased with the exception of the heavy and rapid breathing.
- 6:00 P. M. Heavy breathing continued.
- November 11, 1916.
- 8:00 A. M. The subject was apparently normal.

On November 21, 1916, ten bovines were injected intradermically in the tail fold with a *Gastrophilus* extract prepared in a similar manner as the one above mentioned. In two of those animals a fairly good sized swelling was the result, while in the rest the swellings were small and of a transitory character.

The writers also found occasion to experiment with extract of other parasites. For this purpose a number of specimens of *Ascaris megalocephala*, were weighed, crushed, macerated for 24 hours in ten times their weight of physiologic salt solution, centrifuged, filtered and heated for 1 hour to 60° C. This extract was used for the following ophthalmic test.

Animal

Results

Horse No. 636

April 6, 1917. In 2 minutes there was profuse lachrymation, and in 5 minutes the eye was almost swollen shut. The subject was restless, pawed, shook its head, and showed increased respirations.

5 hours later the parts were still swollen but on the following morning the eye looked normal.

Horse No. 3798

April 6, 1917. The instillation was followed by a moderate reaction. There was lachrymation and a moderate degree of swelling. Constitutional disturbances were not observed. The swelling persisted for a few hours and had disappeared on the following morning.

Horse No. 3813

April 6, 1917. The instillation was followed by a moderate degree of lachrymation and swelling. No constitutional disturbances were seen, and the reaction had ceased 5 hours later.

Horse No. 3814

April 6, 1917. The instillation was soon followed by a marked reaction, as evidenced by swelling and lachrymation, which in 20 minutes reached its maximum. On the following morning the swelling had not entirely disappeared.

Horse No. 3822

April 6, 1917. A marked reaction soon followed the instillation and lasted until the following morning.

As a control experiment the *Ascaris* extract was also instilled in one of the eyes of each of four goats, four dogs, one cat, six rabbits and six caviae. In all these animals the results were absolutely negative.

Some experiments were also made with an *Ascaris* extract prepared in similar manner, but which had been prepared by means of a 50% solution of glycerine in the place of the physiologic salt solution.

Those experiments resulted as follows:

Animal	Results
Horse No. 636	June 14, 1917. Within 1½ minutes after the instillation, lachrymation began and became very profuse after 3 minutes more. The palpebral structures began to swell at about the same time. One and a half hour after the instillation, lachrymation had ceased and the swelling was decreasing. Seven hours later the reaction had practically ceased.
Horse No. 4116	June 14, 1917. Not the slightest reaction followed the instillation.



Figure I. (Horse No. 3822)

Horse No. 3822	June 14, 1917. Lachrymation began within a half minute after the instillation, and soon became profuse. The palpebral tissues began to swell, and after 10 minutes more this swelling was very marked. (See fig. 1) The tear flow continued profusely and ran over the face in streams. The subject attempted to rub the eye from time to time. The conjunctiva became congested. After 25 minutes more, the eye discharge was of a mucous character. After
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Animal	Results
	12 hours the lachrymation had ceased and the swelling had become somewhat reduced. There still was considerable swelling after 7 hours.
Colt No. 3966	June 14, 1917. Lachrymation appeared after about 1 minute and the conjunctiva became injected. After 5 minutes the palpebral tissues began to swell slightly, and the lachrymation increased without becoming profuse.

On the same day, June 14, 1917, a number of work horses were also used in this experiment, but owing to the circumstances under which the observations had to be made, the results could not be described in sufficient detail. We let them follow here for what they are worth.

Animal	Results
Babe	No reaction.
Lee	No reaction.
King	Slight reaction which had disappeared after 6 hours.
Topsy	A moderate degree of reaction which was still visible after 6 hours.
Zelma	Slight reaction which had disappeared after 1 hour.
Polly	A moderate degree of reaction, which after 6 hours was still present.
Roy	A slight but rather persistent reaction.
Dick	A moderate degree of reaction still present after 6 hours.
Dan	A slight reaction, no longer present after 6 hours.
Gypsy	A slight reaction, no longer present after 6 hours.
Frank	No reaction.
Robert	No reaction.
Jim	No reaction.
Riley	Slight reaction, which had disappeared after 6 hours.
Mack	Slight reaction, still visible after 6 hours.
Taft	Slight but persistent reaction.
Johnson	No reaction.
Stella	Slight reaction, which had disappeared after 6 hours.
Loretta	Doubtful reaction of which no sign remained after 6 hours.
Sylvia	No reaction.
Dot	No reaction.
Cora	Slight reaction which had disappeared after 6 hours.
Nellie	No reaction.
Lady	No reaction.
Bertha	No reaction.
Ruby	No reaction.

As a check experiment the glycerine *Ascaris* extract was also instilled in one of the eyes of each of four cavia, ten rabbits and four dogs. In none of these animals could a trace of reaction be observed.

A number of experiments were also made with an extract of the larvae of *Hypoderma lineata*, prepared in the usual manner and heated for 1 hour to 60° C.

On April 16, 1917, three western steers, which had been the hosts of the larvae mentioned had the extract instilled in one of their eyes.

One reacted with slight lachrymation and a moderate palpebral swelling. In the other two the reactions were even slighter and in all three of the animals, all signs of the reaction had completely disappeared on the following day.

Six other steers and three calves, all free from *Hypoderma* larvae were also used in this experiment, and none of those animals showed the slightest evidence of a reaction.

Four dogs, which had instilled into one of their eyes an extract prepared in the usual manner from *Dipylidium caninum*, showed no evidence of a reaction whatever.

While in some of our experiments we failed to obtain the striking reactions described by Hadwen and Bruce (18) in others the results were confirmatory of their findings relative to the allergic sensitization of parasite hosts, against substances of the same parasite.

After reviewing the experiments described above the writers feel warranted to conclude as follows:

1. There is no reason to believe that *Gastrophilus* species play a specific part in the causation of infectious anemia or swamp-fever of the horse.

2. That the severe intoxication following the injection of *Gastrophilus* material into horses are not due to a special substance in the sense of the "Oestrin" of the Seyderhelsms.

3. That such intoxications are purely a manifestation of anaphylaxis and do in no way differ from those precipitated by the use of any foreign protein.

4. Many parasitic species sensitize their hosts who upon reinjection will respond by anaphylactic or allergic reactions.

5. That the acutely toxic properties thus far found to be associated with parasites, owe their toxicity to the specific sensitization of the animal's injected with materials of parasitic origin.

6. That it is reasonable to assume that anaphylactically intoxicating substances of parasitic origin can gain entrance into the body through the same channels which previously served for the entrance of the sensitizing ones.

7. That by a more or less constant presence of certain parasites the body may be constantly supplied by parasitic anaphylatoxins.

8. That it is within the range of possibility that such a form of intoxication may give rise to certain more or less definite disease processes.

If such a parasitic anaphylaxis is thus established a wide field for further experimentation presents itself, and various problems beckon the investigator. What for instance, are the results of a chronic more or less constant anaphylactic poisoning? Can this have any relation to such chronic diseases as anemia, cirrhoses of different kinds, parenchymatous degenerations and other conditions which we have always so readily attributed to auto-intoxication? What, again, is the nature of the changes in the blood of some of our own anaphylactic horses which caused it to produce febrile reactions in other individuals? Many such questions present themselves and may well be answered.

Another very practical question suggests itself in regard to the Hadwen reaction. Could it not be made to serve useful purposes in practice? Would it not be possible for instance by means of this reaction to sort out in a flock of sheep the carriers of *Coenurus cere-*

bralis by means of an eye test made either with the fluids of those cysts or of extracts prepared from the *Tenia coenurus* itself?

The result obtained in our rabbit experiment with the extract of *Tenia serrata* is certainly suggestive.

But above all, should we first attempt to improve the rather crude pharmaceuticals followed in our experiments in the preparation of the parasitic extracts and in the allergic reactions. A greater concentration at least seems necessary. A further possibility is associated with what may be brought to light by the study of this problem in vitro. We have already made some attempts, but have thus far not met with encouraging results. We are certain however, that it is reasonable to suppose that where anaphylactic sensitization can be so strikingly shown in vivo that it can also be demonstrated in the test tube.

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